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PARASITOLOGY

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EDITED BY

GEORGE H. F. NUTTALL, F.R.S.
Quick Professor of Biology in the University of Cambridge

AND

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Reader in Zoology in the University of Cambridge

ASSISTED BY

EDWARD HINDLE, PH.D.

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ISSUED BY THE ADVISORY COMMITTEE APPOINTED BY THE SECRETARY OF STATE FOR INDIA, THE ROYAL SOCIETY AND THE LISTER INSTITUTE.

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THE TREMATODE PARASITES OF NORTH QUEENSLAND. I.

By WILLIAM NICOLL, M.A., D.Sc., M.D.

(*Australian Institute of Tropical Medicine, Townsville, Queensland.*)

(With Plates XXIII and XXIV.)

It is only within the last half-dozen years that any serious attempt has been made to deal systematically with the parasitic worms of Australia. In 1909 Dr T. Harvey Johnston commenced what has proved to be a most extensive and successful survey of the cestode parasites. Dealing at first chiefly with Southern forms, he has latterly (1912) continued his investigations in Queensland and has extended them to include Nematodes and Echinorhynchs. Some years previously (1901) Dr S. J. Johnston of Sydney had started a study of the Trematode parasites, but this did not lead to any outstanding results until last year, when his important paper on the Trematode parasites of Australian frogs appeared. He has followed this up by another important work on Trematodes from North Queensland, which has appeared during the present year.

Dr Georgina Sweet of Melbourne has probably done more than anyone of recent years to initiate and encourage the study of Australian parasitic worms, especially from the economic side, and her "Endoparasites of Australian Stock and Native Fauna" (1909) marks what may be regarded as the beginning of renewed interest in these matters. The observations of earlier workers were chiefly confined to the parasites of domestic animals, and the only really considerable contribution to our knowledge of the parasites of the Australian native fauna was that made by Krefft (1871).

It is thus evident that a large field remains practically untouched, and that is particularly the case in North Queensland, where until recently very few observations have been made. Bancroft showed that many of the Queensland birds were infected with worm parasites but he made no attempt to identify or describe such forms as he met with. Krefft recorded the occurrence of several unidentified Trematodes in Queensland, while the common *Paramphistomum cervi* was found by Cobb (1891) in the ox, and by Krefft (1871) in the sheep. In addition to the cestodes described by Krefft a few forms have been recorded from North-East Australia, chiefly by Zschokke. Only a few, mainly unidentified Nematodes, have been recorded from Queensland, for the most part by Krefft. Von Linstow (1898) has described three other species. Only one Echinorhynch, *Gigantorhynchus semoni*, has been recorded (von Linstow, 1898).

This constituted our entire knowledge of the helminth parasites of Queensland animals prior to the foundation of the Australian Institute of Tropical Medicine in 1910. In that year a thorough systematic investigation of the available native fauna was commenced by Dr Breinl, with the result that a comparatively large collection of worm parasites has been gathered together, many of which are of considerable interest.

Several of these have already been described in the above mentioned papers of T. H. Johnston and S. J. Johnston and in the recently published Annual Report of the Institute (Breinl, 1913).

The collection now contains specimens of 49 species of Trematodes from Queensland and the Northern Territory. Ten of these are already known species, while seven new forms have been described by S. J. Johnston. In the present paper an additional twelve new species are recorded, two of which represent new generic types.

Family **OPISTHORCHIIDAE.**

Genus *Clonorchis* Looss.

Clonorchis sinensis Cobbold.

Two small lots of *Clonorchis*, as well as one mounted specimen, are present in the museum. The mounted specimen and one of the bottles were presented by Dr C. L. Strangman, Port Darwin. The origin of the other lot is unknown. In the specimen presented by Dr Strangman the length varies from 17·5 mm. to 21 mm., and the breadth from 4 mm. to 4·3 mm. The figures exceed the limit usually given for this parasite.

The oral sucker measures 0·63–0·74 mm. with an average of 0·69 mm. in the five specimens measured. The ventral sucker has a diameter of 0·44–0·55 mm., average 0·50 mm. In all the specimens the oral sucker exceeded the maximum limit assigned to it by Looss, but the ventral sucker corresponded more closely in size to the figures given by him. The sucker ratio is on an average approximately 7 : 5 or 1·38 : 1, which approaches sufficiently near the ratio 16 : 12 given by Looss. In one of my specimens, however, the sucker ratio was nearly 18 : 12.

In the second lot of specimens the length was 11–15 mm. and the breadth 2·7–4 mm. They were not so carefully preserved as the previous lot and many of them were much distorted.

They were all quite mature. The oral sucker measured 0·53–0·67 mm. and the ventral 0·45–0·52 mm., the average being 0·60 mm. and 0·48 mm. and the ratio 5 : 4. The dimensions in this lot evidently correspond more closely to those given by Looss for *Clonorchis sinensis* than do those of the previous lot. It is quite possible that the latter were flattened by pressure which might account to some extent for the increased dimensions. In any case, however, it is certain that the oral sucker may occasionally be somewhat larger than the maximum quoted by Looss, and on the other hand that fully mature specimens may be found as small as 11 mm.

The mounted specimen corresponds more nearly to *Clonorchis endemicus* (Baelz). It is 15 mm. in length and has suckers measuring 0·46 mm. and 0·39 mm. respectively. This specimen cannot be ascribed to *C. sinensis* unless it be admitted that the minimum limit (0·52 mm.) given by Looss, for the oral sucker, is too high.

It is unfortunate that the specimens at my disposal were not more numerous so that I might have been able to pass some opinion on the question of the identity of the two species of *Clonorchis*.

Family **FASCIOLIDAE.**

Sub-family FASCIOLOPSINAE.

Genus *Fasciolopsis* Looss.

Fasciolopsis buski (Lank.).

A single specimen of this parasite was presented to the Institute by Dr C. L. Strangman, Port Darwin, but there are no particulars with regard to its origin.

Family **ECHINOSTOMIDAE.**

Sub-family ECHINOSTOMINAE.

Genus *Echinostoma* Rud.

Echinostoma elongatum n. sp.

(Plate XXIII, fig. 1.)

A few specimens of this parasite were collected by Dr Nisbet, Townsville, from the intestine of a night-jar (*Podargus strigoides* ?). They are of moderate size, 6–9·5 mm. in length with a maximum breadth of 0·7–0·8 mm., the broadest part of the body being across the testes. The breadth is fairly uniform, the sides of the body being almost parallel for a considerable part of their length. The breadth of the head is 0·5–0·6 mm. The body is fairly flat and is covered in front of the ventral sucker with numerous cuticular spines.

There are 35 cephalic spines arranged in two unbroken rows and with end groups of four on each side. In one specimen only 33 spines could be made out. The spines vary considerably in length, the limits being 0·06 mm. and 0·095 mm. and the average about 0·08 mm. As a rule the spines in the end group are rather longer than the others, but no constant difference could be detected.

The oral sucker is very small, measuring only 0·11–0·15 mm. in diameter. The ventral sucker, which is situated at a distance of 1·1–1·5 mm. from the anterior end, measures 0·35–0·5 mm. in diameter and 0·55–0·65 mm. in depth. It is oval in outline.

The prepharynx is about 0·08 mm. long and the pharynx measures 0·12 × 0·1 mm. The oesophagus is 0·3 mm. long. The intestinal diverticula extend to the posterior end of the body.

The genital aperture is over the intestinal bifurcation and the cirrus-pouch is short and plump, not extending beyond the middle of the ventral sucker. It measures about 0·5 × 0·2 mm. and contains a large vesicula seminalis, a small pars prostatica and a long ductus and cirrus. The testes lie in the posterior half of the body, the post-testicular space being about 1·4 mm. or rather more than a sixth of the body-length. They lie directly tandem and are separated by a space of about 0·2 mm. They measure on an average 1·0 × 0·46 mm. but the posterior is usually a trifle larger than the anterior testis.

The smaller globular ovary lies 0·3 mm. in front of the anterior testis and has a diameter of 0·22 mm. Behind it lies the shell-gland complex and the receptaculum seminis. The yolk glands occupy the sides of the body from the posterior border of the ventral sucker to almost the tip of the tail. They completely envelope the intestinal diverticula but do not overlap the testes and do not unite in the post-testicular space. The uterus is not very voluminous and contains only about 70 eggs. They are of large size measuring 0·091–0·105 × 0·054–0·073 mm., the average being 0·098 × 0·059 mm.

Echinostoma australasianum n. sp.

(Plate XXIII, fig. 2.)

Four specimens of this species were obtained from the intestine of the native companion (*Antigone australasiana*). It differs very considerably from the foregoing species chiefly in the shape of the ventral sucker and in the position of the genital glands. It is decidedly larger, measuring 13–14 mm. in length. The maximum breadth across the ventral sucker is 1·75 mm. The head is bent towards the ventral surface and there is a pronounced cervical concavity. The neck expands abruptly in front of the ventral sucker and the body thereafter narrows gradually towards the tail. Spines are present on the anterior part of the body as far back as the posterior border of the ventral sucker.

The head has a breadth of 1 mm. and on it are 45 cephalic spines arranged in two unbroken rows. They have the usual disposition and shape, and measure 0·11–0·135 mm. in length. The spines of the anterior row are somewhat longer than those of the posterior row.

The oral sucker is comparatively large, measuring 0·38–0·41 mm. in diameter. There is practically no prepharynx but the pharynx is of large size and measures 0·35 × 0·2 mm. The oesophagus extends backwards to a little in front of the ventral sucker where the bifurcation takes place. The diverticula extend to near the tip of the tail. The ventral sucker is decidedly funnel-shaped. Its diameter is 1·1 mm. but its depth is almost twice as great, namely 2·1 mm. The centre of the aperture is about 2·1 mm. from the anterior end of the body.

The genital aperture is median just behind the intestinal bifurcation. The cirrus-pouch is short and plump and does not quite reach the middle of the ventral sucker. It contains a large convoluted vesicula, a short prostate and a moderately large ductus and cirrus. The vagina is very muscular and extends beyond the posterior border of the ventral sucker.

The anterior testis is situated almost exactly in the middle of the body. The second testis is a very short distance behind it and the post-testicular space measures 5·2 mm. The testes are elongated oval with a decided constriction about their middle. They measure about 1·2 × 0·7 mm., the posterior being slightly the larger.

The transversely oval ovary lies 0·5 mm. in front of the testes. Its dimensions are 0·5 × 0·3 mm. The large shell-gland and the receptaculum seminis lie close behind the ovary. The yolk glands are somewhat voluminous, extending from a little in front of the posterior border of the ventral sucker to within a short distance of the tip of the tail. They do not unite nor do they overlap the testes. The uterus is confined between the ovary and ventral sucker. It contains about 50 eggs which measure 0·105–0·126 × 0·065–0·077 mm.

Of these two species of Echinostoma, *Echinostomum elongatum* bears most resemblance to *E. uncatum* Dietz. It has the same number of cephalic spines, but they are somewhat smaller. The suckers, particularly the oral sucker, and the pharynx are also smaller and the ova are larger. Altogether, apart from the size of the oral sucker, the differences between the two species are very slight. *E. australasianum* is most closely related, perhaps, to *E. sarcinum* Dietz, but differs from it chiefly by reason of the large size of the suckers and the great depth of the ventral sucker.

Genus *Patagifer* Dietz.

Patagifer bilobus (Rud.).

A single specimen of this species was obtained from the intestine of a glossy Ibis (*Plegadis falcinellus*).

Family **DICROCOELIIDAE.**

Genus *Eurytrema* Looss.

Eurytrema crucifer n. sp.

(Plate XXIII, fig. 3.)

A few specimens of this interesting species were found in the gall-bladder of a slow-worm (*Delma fraseri*). It is a small plump species, measuring 0·7–0·8 mm. in length and 0·35–0·4 mm. in greatest breadth. The outline is almost oval but the neck narrows very abruptly. There are no spines on the cuticle.

The oral sucker has a diameter of 0·18 mm. and the smaller ventral sucker 0·15 mm. The latter is situated 0·35 mm. from the anterior end of the body. Both suckers are globular with wide apertures.

There is no prepharynx. The moderately large pharynx has a diameter of 0·04 mm. and it is followed by a somewhat shorter oesophagus. The intestinal diverticula in most specimens are greatly dilated and extend almost to the posterior end of the body.

On each side of the posterior half of the ventral sucker lies a small round testis, with somewhat crenated margin and having a diameter of 0·04 mm. Just behind the sucker and slightly to the left side lies the globular ovary which is about the same size as the testes. The yolk glands are situated to the outer side of the intestinal diverticula, and overlapping the latter to a considerable extent. They extend from the testes to a short distance behind the level of the ovary. They are very compact. The transverse yolk ducts cross behind the ovary. The uterus, especially in the less mature specimens, has a characteristic cruciform course. It runs backwards from the ovary to the tip of the tail, where it makes a turn to one side or the other and then returns. When it reaches the level of the yolk glands it makes a single transverse convolution across almost the whole breadth of the body and finally forms one or two loops just behind the ventral sucker. In more mature specimens this arrangement is, to some extent, obliterated. The eggs are not numerous and measure 0·03–0·033 × 0·021 mm. Posteriorly they are light in colour but in the transverse convolution and in front of it they are dark brown, and enclose fully developed miracidia.

The genital aperture is median, just behind the intestinal bifurcation. The cirrus-pouch is small and inconspicuous, and does not reach the ventral sucker.

Genus *Mesocoelium* Odhner.

Mesocoelium microon n. sp.

(Plate XXIII, fig. 4.)

This species was obtained from the duodenum of *Hyla coerulea, H. gracilenta* and *Tiliqua scincoides.* It is very common and usually occurs in numbers of from 10 to 40 in each host.

It is a moderately small species, measuring 1–2 mm. in length. In pressure preparations the length may be as much as 3·5 mm. No specimens under 1 mm. were obtained and one measuring 1·1 mm. was fully mature. In three of the larger specimens the average length was 1·94 mm. and the greatest breadth, just behind the ventral sucker, was 0·77 mm. The outline is elongated oval, pointed at both ends.

The cuticle is covered with minute closely-set spines which disappear gradually towards the posterior end. The oral sucker, which is usually elongated longitudinally and which has an elongated aperture, measures 0·25 mm. in diameter. The ventral sucker which is usually transversely elongated measures 0·18 mm. in diameter. The ratio of the suckers is therefore considerably less than 3 : 2. The ventral sucker is situated at a distance of 0·57 mm. from the anterior end.

The pharynx is almost contiguous with the oral sucker and measures 0·08 mm. in length and breadth. The oesophagus is twice as long as the pharynx, and the intestinal diverticula extend a little beyond the middle of the body.

The excretory vesicle extends forward to a short distance behind the receptaculum seminis.

The genital aperture is situated in the middle line a little in front of the intestinal bifurcation. The short slender cirrus-pouch reaches back to just in front of the ventral sucker. It contains a small vesicula seminalis, an almost globular pars prostatica and a long ductus ejaculatorius.

The testes are situated on the level of the ventral sucker and overlapping it to some extent. They are rarely symmetrical, the left usually being a little in advance of the right. They are irregularly rounded bodies measuring about 0·21 × 0·14 mm. There is considerable variation in their position, size and shape.

The ovary lies on the left side almost immediately behind the left testis. It is a large rounded or somewhat heart-shaped body measuring 0·15 mm. in diameter. On its inner side lies the shell-gland complex with a small receptaculum seminis. The yolk glands extend from the oral sucker to near the end of the intestinal diverticula. Behind the ventral sucker they are confined for the most part to the outer side of the diverticula, but in front of the sucker they spread out, overlapping the intestines and in some cases almost uniting dorsally to the oesophagus. The uterus is very voluminous and contains a large number of eggs. From the ovary it winds back on the left side to the posterior end of the body. It returns on the right side but about the middle of the body it forms a convolution which extends right across the body. It then continues up on the right side, crossing the right testis. The eggs measure 0·033–0·041 × 0·024–0·028 mm., the average being 0·038 × 0·026 mm.

The species is subject to a number of small variations which chiefly affect the position of the genital glands.

Remark has already been made on the variability of the testes. The same applies to the ovary and the receptaculum seminis. The yolk glands also vary in extent. In one case they were entirely absent on one side behind the ventral sucker. In another specimen they were so poorly developed as to be almost non-existent. In the same specimen the uterus or, rather, the oötype appeared to be functioning imperfectly, for the eggs were badly shaped and much scattered. This individual further showed amphitypy and in addition the intestinal diverticula ended immediately behind the ovary. It was a specimen from *Tiliqua scincoides* and it was the only one in which these abnormalities occurred.

Family **LEPODERMATIDAE.**

Genus *Lepoderma* Looss.

Lepoderma nisbetii n. sp.

(Plate XXIII, fig. 5.)

Only two specimens of this species were obtained from the intestine of a drongo (*Dicrura bracteata*). They were somewhat macerated but sufficient details remained to enable a definite description to be made.

The worm has the typical *Lepoderma* shape and measures 1·25 mm. in length. The greatest breadth, across the ventral sucker, is about 0·4 mm. The cuticle is closely beset with short spines which disappear towards the posterior end.

The oral sucker measures 0·22 × 0·24 mm. and the ventral sucker 0·15 × 0·14 mm., the ratio being a little over 3 : 2. The ventral sucker is situated at a distance of 0·34 mm. from the anterior end. The pharynx is contiguous with the oral sucker and there is practically no oesophagus. The intestinal diverticula extend almost to the posterior end of the body.

The genital aperture is median and lies over the intestinal bifurcation. The cirrus-pouch is small and does not reach much beyond the centre of the ventral sucker. The ovary lies 0·1 mm. behind the ventral sucker and slightly to the right side. It is a globular body with a diameter of 0·11 mm. The anterior testis is 0·04 mm. behind the ovary, from which it is separated by the uterus. It is on the left side and is elongated oval with a long diameter of 0·1 mm. The posterior testis lies on the right side, half a diameter behind the anterior testis, and it is slightly larger than the latter.

The yolk glands extend from midway between the suckers to the posterior end of the body. They do not unite and are of fairly uniform width, overlapping the intestinal diverticula along their whole length.

The uterus has the disposition characteristic of the genus. It winds back from the ovary between the testes and fills a considerable part of the post-testicular space. It returns the same way and passes forward to the genital aperture. The eggs are not very numerous. They measure 0·030–0·032 × 0·015–0·016 mm.

Genus *Dolichopera* n. g.

Dolichopera parvula n. sp.

(Plate XXIV, fig. 6.)

Two specimens of this interesting species were obtained from the intestine of a carpet snake (*Python variegatus*). It is a small delicate species with rounded anterior end and sharply pointed posterior. The measurements taken from a slightly pressed specimen are:—length 2·4 mm., maximum breadth 0·7 mm. just in front of the ventral sucker. The cuticle is covered with short spines which disappear behind the ventral sucker. The oral sucker has a diameter of 0·41 mm. and the ventral 0·34 mm. The latter is situated at a distance of 1·51 mm. from the anterior end of the body. The pharynx is almost contiguous with the oral sucker and has a diameter of 0·09 mm. The oesophagus is about as long as the pharynx and the diverticula extend right to the posterior end of the body, curving inwards behind the ventral sucker.

The genital aperture lies near the right margin of the body on the level of the posterior half of the oral sucker. The cirrus-pouch is slender and lightly curved. It stretches obliquely from the genital aperture to the intestinal bifurcation. It contains a simple bipartite vesicula seminalis, a small bulbous pars prostatica, and a short ductus ejaculatorius. Its dimensions are 0·26 × 0·08 mm. The ovary lies over the right posterior quadrant of the ventral sucker, and somewhat behind it. It is oval with its long axis oblique. The testes are almost symmetrical and lie about 0·1 mm. behind the ventral sucker. The left is a little in advance of the right, and they are separated by a space of 0·12 mm. They are longitudinally oval bodies with a long diameter of about 0·18 mm. They lie close to the intestinal diverticula.

The yolk glands are very scanty, consisting of a few small follicles confined to the outer side of the intestinal diverticula and extending from the middle of the ventral sucker to the middle of the testes. The uterus is very voluminous and fills up the whole of the anterior part of the body behind the pharynx. It also completely encircles the ventral sucker and winds back between the testes for a short distance, but only comparatively few ova are found behind the ventral sucker. The ova measure 0·036–0·043 mm. in length, and 0·021–0·024 mm. in breadth, the average being 0·039 × 0·022 mm.

This trematode bears a close resemblance to the species described by MacAlpine (1891) from the tiger snake (*Hoplocephalus superbus*), specimens of which I owe to the courtesy of Dr Sweet of Melbourne. MacAlpine's species, however, is considerably larger and has a much longer cirrus-pouch. It may be included in the same genus and for it I propose the name *Dolichopera macalpini.*

The chief characteristics of the new genus *Dolichopera* may be summed up as follows :—*Lepodermatidae* of small to moderate size, elongated and somewhat flat. Cuticle covered with spines. Ventral sucker smaller than oral sucker and situated behind the middle of the body. Oesophagus short and diverticula extending to near posterior end of body. Genital aperture between the oral sucker and the margin of the body, on the right or left side. Cirrus-pouch sinuous and elongated. Ovary behind the right posterior quadrant of the ventral sucker. Testes behind the ovary near the posterior end of the body, longitudinally oval and somewhat asymmetrical, the left testis being in advance. Yolk glands entirely lateral in the posterior part of the body. Uterus very voluminous, filling up the whole of the middle of the body, and passing between the testes only for a very short distance. Ova 0·03–0·04 mm. in length and about 0·02 mm. in breadth.

Type. *D. parvula* Nicoll.

Habitat. Intestine and lungs (?) of snakes (Australia).

Genus *Aptorchis* n. g.

Aptorchis aequalis n. sp.

(Plate XXIV, fig. 7.)

Only a single specimen of this form was obtained from the intestine of a turtle (*Emydura latisternum*). It is a small flat species the posterior part of which is broad and rounded. The width diminishes gradually towards the anterior end which is pointed. The cuticle is beset with moderately large spines.

The length is 2·1 mm. and the greatest breadth 0·85 mm. The oral sucker is globular, with a diameter of 0·21 mm. The ventral sucker measures 0·31 mm. and is situated 0·82 mm. from the anterior end of the body.

There is a distinct prepharynx, 0·1 mm. in length. The pharynx measures 0·135 × 0·105 mm. and the oesophagus 0·06 mm. The intestinal diverticula are short. They keep close to the ventral sucker and terminate a short distance behind it, the ends being obscured by the uterus. At the intestinal bifurcation the initial parts of the diverticula are somewhat swollen.

The genital aperture is situated a little in front of the ventral sucker, over the left intestinal diverticulum. The cirrus-pouch is a long, slender and sinuous structure which extends a little beyond the posterior border of the ventral sucker. It was found impossible to make out with accuracy the details of its internal structure. There appears to be a somewhat capacious genital sinus. The testes lie exactly midway between the ventral sucker and the posterior end of the body. They are symmetrically situated, transversely oval in shape and are separated by a space of 0·24 mm. Their dimensions are 0·11 × 0·18 mm. They are only slightly obscured by the uterus.

The ovary lies midway between the ventral sucker and the testes. It is almost median, somewhat oval, and measures 0·10 × 0·13 mm. No receptaculum seminis could be detected. The yolk glands are entirely lateral and extend from a little behind the ventral sucker to the posterior end of the body where, however, they do not unite. They are slightly higher on the left than on the right. They extend in from the edges of the body a considerable distance and overlap the uterus in places. The uterus is very voluminous. Starting from the oötype, it passes back between the testes and forms a number of convolutions in the post-testicular space. Passing forward again it fills up the greater part of the body behind the ventral sucker. The numerous ova measure 0·028–0·031 × 0·018–0·019 mm.

The inclusion of the two preceding forms within the family *Lepodermatidae* must be regarded as somewhat doubtful. They both depart from the typical arrangement in having the testes well nigh symmetrical, though in each there is a tendency for the left testis to be a little in advance of the right. This is barely perceptible in *Aptorchis.* The position of the ovary in the latter is also somewhat atypical, while the yolk glands have an unusual disposition. In *Dolichopera* the position of the uterus is unique. In spite of the large number of genera which have now been included in the family it is surprising that there yet appears no possibility of arranging them in sub-families. Practically no other family of Distomate Trematodes shows such a conflicting diversity of form and structure.

Family **CEPHALOGONIMIDAE.**

Genus *Prosthogonimus* Luhe.

Prosthogonimus vitellatus n. sp.

(Plate XXIV, fig. 8.)

Two specimens of this species were obtained from the bursa fabricii of a drongo (*Dicrura bracteata*). Unfortunately both were damaged in collecting, but one was in a sufficiently good state to permit of a fairly accurate description. It is a moderately large form measuring 5 mm. in length and 2·6 mm. in maximum breadth. The body is roughly oval in outline but there is a slight constriction just in front of the ventral sucker and from there the neck narrows very rapidly to the pointed anterior end. The posterior end of the body is rounded. The cuticle is covered with stout spines in the anterior half of the body and these are present both on the ventral and dorsal surfaces. The oral sucker is elongated and measures 0·53 × 0·33 mm. The ventral sucker is almost globular, measuring 0·66 × 0·71 mm. It is situated at a distance of 1·58 mm. from the anterior end of the body, so that the neck is almost a third of the body-length. Contiguous with the oral sucker is a large pharynx, measuring 0·2 × 0·18 mm. The oesophagus is about the same length (0·21 mm.) and the wide intestinal diverticula extend to within 0·8 mm. of the posterior end of the body (twice the length of the testes behind the posterior border of the testes). Behind the testes the diverticula gradually bend in towards the median line, and their ends are somewhat inflated.

The genital aperture is situated to the left of the mouth, near the margin of the body. The cirrus-pouch is a long sinuous structure extending backward to a little behind the intestinal bifurcation. The two large testes lie almost immediately behind the ventral sucker, and are bounded on their outer side by the intestinal diverticula. They are separated from each other by a space of 0·46 mm. They are symmetrically situated, elongated oval in outline and measure about 0·73 × 0·53 mm. They are overlapped to some extent by the uterus.

The ovary lies dorsal to the posterior half of the ventral sucker and somewhat to the right side. It is a large, deeply-lobed body measuring 0·72 mm. in greatest diameter (transverse). Close to its left side lies a fairly large shell-gland. The yolk glands lie mainly to the outer side of the intestinal diverticula but a certain number of follicles are found on the inner side, especially anteriorly. In this respect the specimen was somewhat asymmetrical, the glands on the right side extending further inwards than those on the left. Their anterior limit is just behind the intestinal bifurcation, and posteriorly they reach the posterior border of the testes. The yolk ducts cross and unite behind the ovary. The uterus fills up the posterior half of the body in the manner characteristic of the genus. It overlaps the intestinal diverticula, the testes and the ovary. The numerous eggs are small and measure 0·025–0·03 × 0·013–0·017 mm., the average being about 0·028 × 0·015 mm.

This species differs from *P. ovatus* in several respects, but chiefly in the size of the suckers. It bears more resemblance to *P. cuneatus* but differs from it in the greater extent of the yolk glands and in the somewhat larger size of the eggs. The extent of the yolk glands along with other features differentiate it from *P. anatinus* and *P. pellucidus*.

Family **HOLOSTOMIDAE.**

Genus *Hemistomum* Diesing.

Hemistomum brachyurum n. sp.

(Plate XXIV, fig. 9.)

A few specimens of this species were obtained from the intestine of a spotted owl (*Ninox maculata*). It is a small form measuring only 1·5–2 mm. in length with a maximum breadth of 0·55–0·7 mm. Of the total length the anterior expanded portion comprises $\frac{5}{8}$. The "tail," or rather the posterior part of the body, is therefore considerably shorter than the anterior part. It is also much narrower, being only 0·35–0·5 mm. in breadth. The edges of the anterior part of the body are well turned over and almost opposed along half their length. The surface of the expanded portion is covered with tiny spines.

The small oral sucker has a diameter of 0·06 mm.; the ventral sucker measures 0·105 mm. and is situated at a distance of 0·57 mm. from the anterior end, *i.e.* exactly in the middle of the anterior part of the body. The adhesive disc has a diameter of 0·23–0·30 mm. and is separated from the ventral sucker by a space of 0·05 mm. It is elevated about 0·13 mm. above the surface of the body.

The pharynx is contiguous with the oral sucker and measures 0·05 × 0·037 mm.; the oesophagus is 0·066 mm. in length and the intestinal diverticula extend right to the posterior end of the body, not diverging very far from the median line at any part of their course. In the anterior part of the body they are somewhat dorsal in position but on passing into the posterior part they become ventral.

The transversely oval ovary measures 0·20 × 0·14 mm. and is situated exactly at the junction of the anterior and posterior parts of the body. The testes lie a short distance behind the ovary; they are large and broad and stretch right across the whole breadth of the body. They are almost contiguous with each other and their diameter in the long axis of the body is 0·14 mm. The large shell-gland lies between the testes and dorsal to them. There is no receptaculum seminis but the initial part of the uterus, which is highly convoluted, is packed full of sperms. A long convoluted Laurer's canal is present.

The yolk glands fill up a large portion of the anterior part of the body, extending into the rolled edges almost to their margin. Their anterior limit is the intestinal bifurcation. Passing into the posterior part of the body they withdraw from the lateral fields and are entirely median. Behind the testes they again spread out to the sides of the body, separating as they do so and leaving a clear space at the tail. The uterus fills up the median field of the posterior part of the body and there are occasionally a few eggs in the anterior part as well. There are usually about 20 eggs which measure 0·1–0·102 × 0·057–0·066 mm. The vagina is thick walled and considerably twisted.

The bursa copulatrix, situated at the posterior end of the body, opens by a wide terminal aperture which is directed obliquely towards the dorsal surface. Through the aperture projects the comparatively large genital papilla. The large highly convoluted vesicula seminalis lies immediately behind the posterior testis. There is a wide and fairly long ductus.

Genus *Strigea* Abildgaard.

Strigea promiscua n. sp.

Numerous specimens of this form were obtained from the intestine of a spotted owl (*Ninox maculata*) and of a boobook (*N. boobook*). It is of moderate size, measuring 2·3–3·5 mm. in length. The maximum breadth of the posterior part is as great as, usually greater than, the breadth of the anterior part, and is about a $\frac{1}{4}$ of the length. The anterior portion comprises about $\frac{2}{5}$ of the total length, and it is almost ovoid in shape. The posterior portion is more cylindrical.

The oral sucker has a diameter of 0·17 mm. and is situated on the pointed anterior margin of the body. The pharynx is contiguous with the oral sucker and measures 0·15–0·17 mm. in diameter. The oesophagus is twice as long as the pharynx and the intestinal diverticula extend almost to the posterior end of the body. In the posterior part they approach the ventral surface. The ventral sucker has a diameter of about 0·25 mm.

The ovary is situated a little behind the middle of the body and measures 0·5 × 0·25 mm. It is a kidney-shaped organ with the hilum directed backwards. The two large testes lie immediately behind the ovary and are contiguous with each other. They extend across the whole breadth of the body. Their edges are crenated.

The yolk glands extend from near the oral sucker along the whole length of the body. In the anterior part they fill up the whole breadth of the body, but in the testicular region they are restricted to narrow bands running along the ventral surface of the intestinal diverticula. They enter the pedicle of the adhesive disc and the ventral wall of the cup. The shell-gland complex lies between the testes and dorsal to them. Laurer's canal is present and the initial part of the uterus is filled with sperms. The uterus fills up the middle field of the whole posterior part of the body and contains numerous large eggs measuring 0·103–0·105 × 0·07–0·075 mm. The highly convoluted vesicula seminalis lies immediately behind the testes and opens on to a rather small genital papilla, which is enclosed in a bursa copulatrix of moderate size. The aperture of the bursa has a very slight dorsal inclination.

This species does not correspond with any of the already known Australian Holostomids. It bears closest resemblance to the European *Strigea gracilis*, but differs from it in having yolk glands throughout the whole length of the body.

Strigea flosculus n. sp.

A few somewhat macerated specimens of this species were obtained from the intestine of a night-jar (*Podargus strigoides*). They were not in a particularly good state for examination but sufficient details could be made out to show that they belong to a new species. The specimens are delicate and slender and measure 1·6–2·4 mm. in length. The anterior portion, which is shaped like a half-open rose bud, has a length of 0·55–0·7 mm. and its breadth is only slightly less (0·5–0·6 mm.). The posterior portion is almost fusiform, a little more than twice the length of the anterior portion, and about 0·4 mm. in maximum breadth. The two portions are separated by a marked constriction where the breadth is only 0·2 mm. The whole body is curved in a semi-circle, the dorsal surface forming the concavity.

The dorsal lamella of the clinging-plug projects only slightly beyond the edge of the cup. The ventral lamella is entirely within the cup and its anterior edge is thickened and rolled over dorsally. The edge of the cup is very oblique so that its ventral lip is almost on the level of the ventral sucker.

The oral sucker has a very prominent anterior lip and its diameter is 0·075 mm. The ventral sucker is deeply sunk, about 0·25 mm. from the head and has a diameter of 0·115 mm. The pharynx, which is contiguous with the oral sucker, measures 0·055 × 0·04 mm. The oesophagus is short.

The moderately large testes are situated close behind one another in the second half of the posterior portion of the body. The smaller ovary lies just in front of the anterior testis. The shell-gland complex lies between the testes. The yolk glands are voluminous, extending along the whole ventral surface of the posterior portion of the body and penetrating into the anterior portion at least as far as the level of the ventral sucker. They occur in the lamella of the clinging-plug as well as in the walls of the cup.

The uterus is not extensive and contains only a few eggs. It forms a few convolutions in front of the ovary and then passes ventrally towards the genital papilla. The ova measure 0·100–0·105 × 0·07 mm. The genital papilla is of moderate size. The voluminous and highly-convoluted vesicula seminalis lies dorsal and posterior to the second testis.

Tetracotyle tiliquae n. sp.

In a blue-tongued lizard (*Tiliqua scincoides*) a number of small, intensely white spots were observed beneath the peritoneum of the abdominal wall. They were oval in outline and measured about 1–2 mm. in long diameter. They were found to consist of a soft cyst wall enclosing a mass of opaque matter, in the middle of which was a transparent oval cyst 0·4 mm. in long diameter. The wall of this inner cyst was about 0·009 mm. in thickness. Within it was enclosed a small larval Holostomid.

The parasite has the typical appearance of a *Tetracotyle* larva, and measures 0·3 mm. in length by 0·19 mm. in breadth. The small oral sucker has a single well-marked glandular pit on either side. The ventral sucker is slightly larger than the oral. Close behind it lies a somewhat kidney-shaped discus. There is a small pharynx, a moderately long oesophagus and diverticula extending almost to the posterior end of the body. No other organs were visible.

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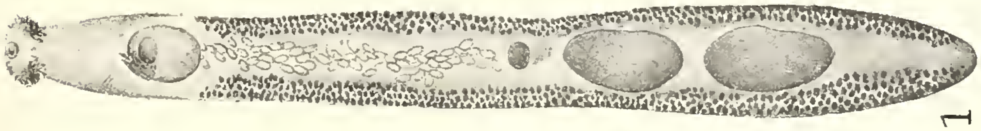
EXPLANATION OF PLATES XXIII, XXIV.

The following letters apply to all the figures:

C.B.	Cirrus-pouch.	*P.G.*	Genital aperture.
Ex.	Excretory vesicle.	*R.S.*	Receptaculum seminis.
Ov.	Ovary.	*T.*	Testes.

Fig. 1. *Echinostoma elongatum* (× 13).
Fig. 2. *Echinostoma australasianum* (× 8).
Fig. 3. *Eurytrema crucifer* (× 133).
Fig. 4. *Mesocoelium microon* (× 33).
Fig. 5. *Lepoderma nisbetii* (× 67).
Fig. 6. *Dolichopera parvula* (× 33).
Fig. 7. *Aptorchis aequalis* (× 50).
Fig. 8. *Prosthogonimus vitellatus* (× 20).
Fig. 9. *Hemistomum brachyurum* (× 44).

All the figures are drawn from the ventral surface.



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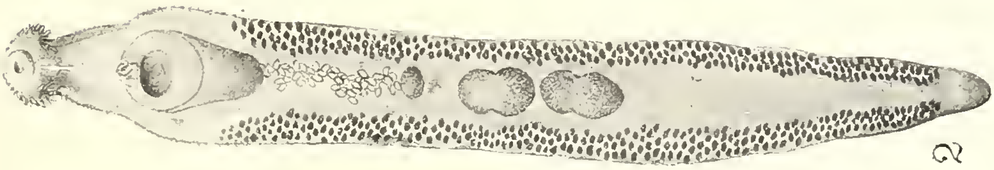

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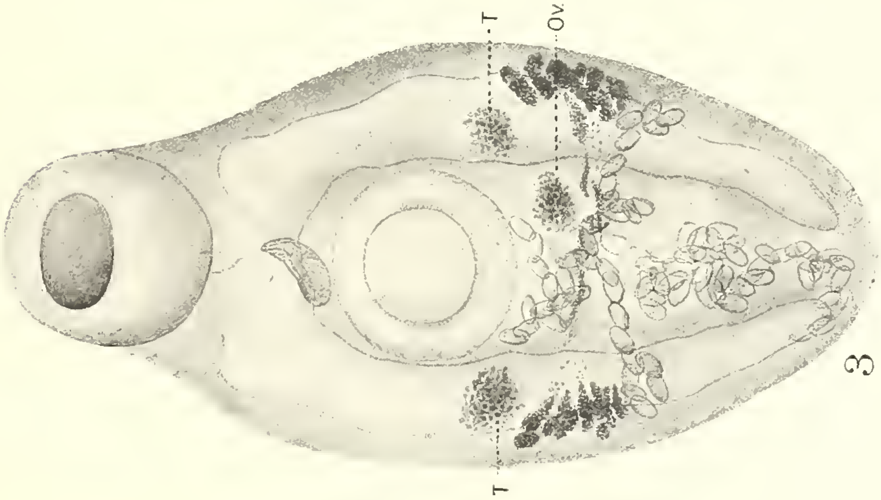

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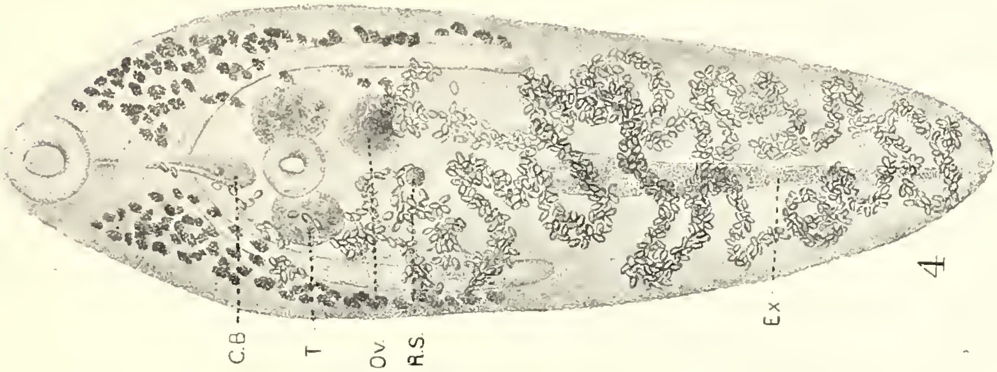

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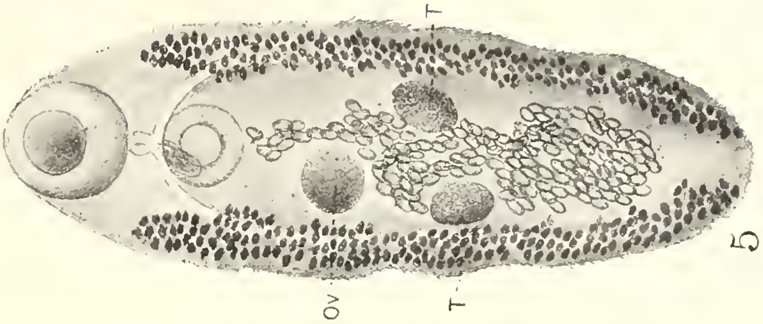

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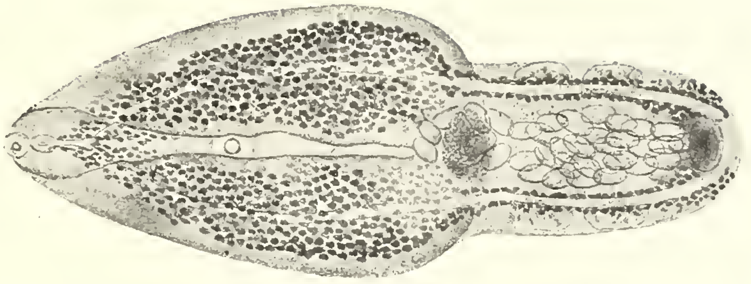

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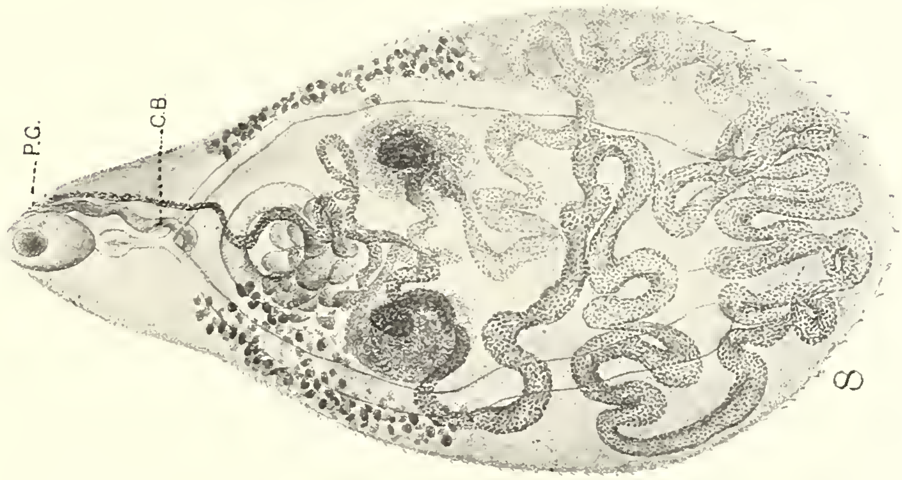

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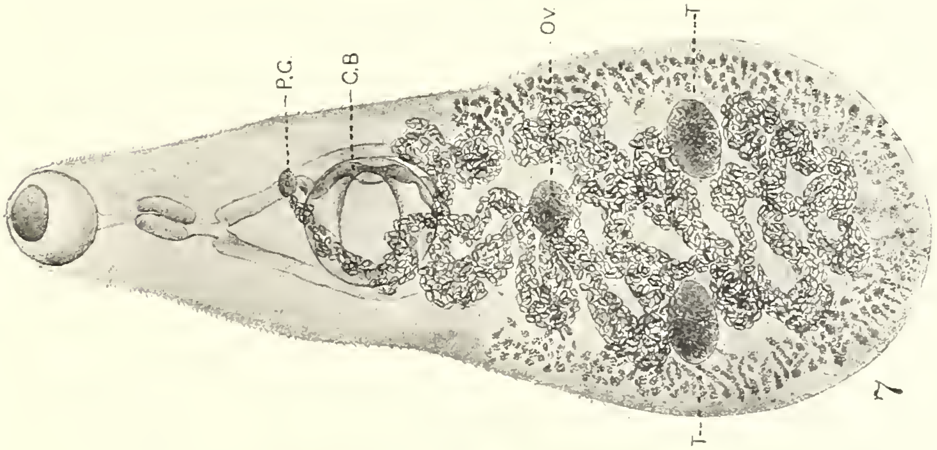

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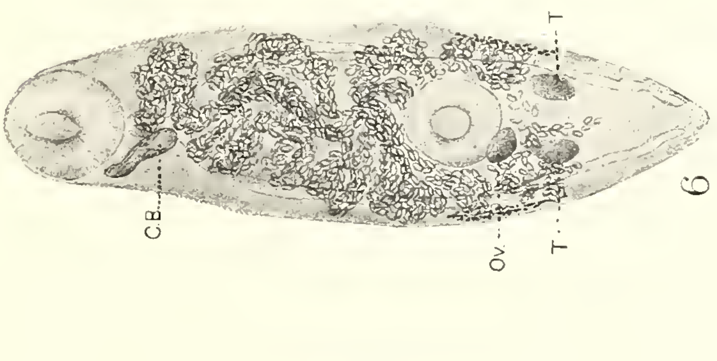

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PSEUDO-PARASITISM.

By A. E. SHIPLEY, Sc.D., F.R.S.

Two very curious cases of pseudo-parasitism have recently come before my notice:—

(1) Towards the middle of last year some centipedes were forwarded to me which had been vomited and passed by a women of 68 years of age. Some of the centipedes emerged through the patient's nose, and it must be mentioned that she was also suffering from a round worm. One of her doctors was of opinion that the centipedes were certainly breeding inside the lady's intestine, and as many as seven or eight, sometimes more, were daily leaving the alimentary canal.

According to her medical attendant's statement these centipedes had left the body in some hundreds during a period of twelve or eighteen months. Their presence produced vomiting and some haematemesis, and treatment with thymol, male-fern and turpentine had no effect in removing the creatures.

As soon as the specimens were sent to me I recognised them as belonging to the genus *Geophilus* and my friend Mr F. G. Sinclair, the well-known authority on the Myriapoda, identified them as specimens of the species *G. gorizensis* Latzel which is equivalent to the *G. subterraneus* of Leach and Newport.

It seems to me quite impossible that these centipedes could have multiplied in the lady's intestine. The breeding habits of the genus *Geophilus* are peculiar, and ill adapted for reproducing in such a habitat. The male builds a small web or nest, in which he places his sperm, and the female fertilizes herself from this nest or web, and when the eggs are fertilized they are again laid in a nest or web in which they incubate and in two or three weeks hatch out. The young *Geophilus* differ but very little from the adult, except in size. It is just possible, but improbable, that a clutch of eggs had been swallowed by the host when eating some vegetables or fruit, but against this is the fact that the *Geophilus* does not lay its eggs upon vegetables or fruit, but upon dry wood or earth. The egg shell is very tough and if the eggs had been swallowed the egg shells could certainly have been detected if the dejecta were examined. The specimens of the centipede showed very little signs of being digested, and it is almost impossible to reconcile the story of the patient with what one knows of the habits of the centipedes.

It may however be mentioned that two species, *G. maritimus* and *G. submarinus*, lead a semi-aquatic life and Plateau states that these species can exist from twelve to seventy hours when immersed in sea-water and from six to ten days in fresh-water. "They," as Mr Sinclair writes, "offer a striking example of the power their class possesses of existing under unfavourable circumstances."

Dr Theodore Thompson has kindly supplied the following clinical details:

"Examined by me July 1912, her tongue was dry and glazed and covered with dry blood. The fauces were dry and glazed. There was bleeding taking place from the nose and I saw a living centipede she had just extracted from her nostril. Her heart, lungs and abdomen appeared normal. She was not very wasted, and did not think she had lost much flesh, nor was there any marked degree of anaemia.

"Dr Sutton who has attended her for eighteen months says he has seen some hundreds of the centipedes during that time. The patient does not eat watercress but while in Scotland ate a lot of lettuces and fruit four years ago and thinks she got infected while there.

"Professor Glynn of Liverpool examined the blood and said it was normal.

"I did a differential count of a blood slide and counted 200 white cells.

"Result. Proportion of white cells to red cells normal: no nucleated red cells seen: polynuclears 76 %: lymphocytes 23 %: eosinophile cells 1 %."

(2) A few weeks ago an organism, slightly digested, was sent to me which had passed through the alimentary canal of a doctor. It had been identified as a Trematode, but it appeared to be a slug. I therefore sent it to Mr Collinge of Birmingham who tells me it is a specimen of *Milax marginatus* (Müll.). It is difficult to understand how so soft a creature could pass through the alimentary canal without being digested, but in the Collinge collection of the Pulmonata in the Museum of Zoology and Comparative Anatomy at Cambridge, there are specimens of an undetermined species of *Veronicella* which had passed through the intestine of a horse at Lagos. These slugs show even less signs of digestion than the *Milax marginatus*.

REGENERATION IN *ARGAS PERSICUS.*

By EDWARD HINDLE, B.A., Ph.D.,
Assistant to the Quick Professor of Biology,
AND NORMAN CUNLIFFE, B.A.,
Student in Medical Entomology.

(*From the Quick Laboratory, Cambridge.*)

(With 4 Text-figures.)

General Introduction.

The present investigation was primarily undertaken by Mr G. Merriman at the suggestion of Professor Nuttall, but was discontinued at a very early stage owing to Mr Merriman's departure for Africa. The object of the investigation was:

(1) To determine if immature stages of ticks whose mouth-parts have been mutilated or torn off by the forcible removal of the parasite from the host possess the power of regeneration. In nature, many immature ticks must be injured in this manner, and it seemed of interest to determine if they could regenerate the lost parts, thus helping them in the struggle for existence.

(2) To determine if the small legs occasionally observed in nymphal and adult ticks are due to mechanical injury followed by regeneration. A very striking example of such a tick is the type specimen of *Amblyomma scaevola* Oudemanns (♂), in which four legs are markedly under-developed. In the large quantity of tick material that has been received at the Quick Laboratory, individuals with one or more miniature legs have been observed repeatedly.

In addition, the subject is one possessing considerable interest from a general point of view, as hitherto there have been extremely few observations upon regeneration in the Arachnida and, so far as we are aware, none in the Ixodoidea.

The present paper contains a short account of the regeneration of the limbs in *Argas persicus*. In a future communication we propose to describe also the regeneration of the mouth-parts.

Historical.

The first author to describe regeneration in an Arachnid was Lepeletier (1812), who noted that in spiders regenerated legs were normally jointed but shorter and darker than the other legs. J. Banks (1829) and Heineken (1829) also observed regeneration of spiders' legs. Heineken noticed that after amputation of a limb the stump remained unchanged until the next moult, and then regeneration processes commenced, extending through two or three moults. The same observer remarks that in fully grown spiders moulting and regeneration do not take place.

Wagner (1887) observed that in the tarantula when a leg was removed at any place other than the coxa, the animal brought the wounded leg to its jaws and bit it off down to the coxa.

In addition to the above, a number of writers have recorded the regeneration of the legs of spiders and the subject has been investigated experimentally by Schultz (1898) and Friedrich (1906).

Schultz, working mainly with the Epeiridae, found that the leg was renewed if cut off at any level; in his experiments he generally removed the leg at the metatarsus, but also at the tibia, and usually at an articulation.

Although these individuals, unlike the tarantula, never attempted to bite off any part of a wounded leg, yet when the leg was cut off at the coxa it regenerated better than when amputated at any other level.

Schultz considers that this is an excellent example of the influence of natural selection, since regeneration takes place best at the point where the leg is most often broken off in nature. On the other hand, regeneration also takes place when the leg is cut off at any other point, thus showing that the power to regenerate is characteristic of all parts of the limbs and not merely a phenomenon of adaptation, for it is unlikely that a spider would ever lose a leg in the middle of an article, the joints being much the weaker. When the leg is cut off between two articles, the formation of the new part takes place somewhat differently than when the leg is cut off at the coxa. In the latter case, a solid rod is produced from the cut end and this rod increases in length, bending on itself several times. Subsequently the rod becomes segmented and at the next moult is set free as a perfect leg. When the limb is removed nearer the distal extremity a small straight rod is formed, lying inside the last article, and the regenerated part is set free at the next moult.

More recently Friedrich (1906) has given a detailed account of regeneration and autotomy in *Tegenaria domestica*, the common house spider. So far as we are aware the only other observations on regeneration in Arachnida are those of Loeb (1895), who found that if the body of the pycnogonid *Phoxichilidium maxillare* is cut in two, there regenerates from the posterior end of the anterior half a new body-like outgrowth.

Material and methods.

In the following experiments the tick *Argas persicus* Oken has been employed throughout, mainly because of the ease and rapidity with which it can be reared in the laboratory. The ticks were generally maintained at 30° C., at which temperature the life-cycle is briefly as follows:

The adult female, after fertilisation, lays a batch of about 60 eggs approximately 8–12 days after engorgement; these eggs, after an incubation period of about 10 days, hatch out to hexapod larvae.

The latter, when placed upon a fowl, attach themselves and remain feeding for 4–6 days, during which period they increase very considerably in size. Finally the gorged larvae drop off the fowl and seek refuge in any crevice, and after about 7–12 days moult to eight-legged first stage nymphs.

The first stage nymphs, when placed upon a fowl, gorge themselves with blood and drop off within half-an-hour, thus differing markedly from the larvae. About 12 days after engorgement they moult to second stage nymphs. The latter feed in exactly the same way as the first stage nymphs and after a period of about 14–18 days moult again, in the majority of cases giving rise to the adult stage. In certain cases, however, the tick may pass through more than two nymphal stages, but usually the life-cycle of the tick comprises only the stages: egg, larva, first and second stage nymphs, adult. The adult tick does not moult, but will feed at intervals of about a month and a fertilised female generally lays a batch of eggs after each feed.

In our experiments the ticks were kept in glass-topped pill-boxes containing filter paper and were maintained at any desired temperature in incubators. The amputation of the various parts of the legs, a matter of some difficulty in the smaller stages, was best effected by placing the tick, in its normal position, on a piece of card under a binocular dissecting microscope; the limb, or part of the limb, was then removed by means of a fine needle ground to a knife-edge, the tick being kept stationary by means of a camel-hair brush. During this operation it is essential that no considerable pressure should be applied to the body of the tick, as in this case the loss of coelomic fluid is so great that the animal dies.

Larva.

Our experiments with the larvae may be divided into two groups. In the first instance we used ticks that had gorged themselves and dropped off the fowl, but later we adopted the plan of cutting off the legs whilst the larvae were still attached. The results of the first series of experiments were mainly negative, and this is noteworthy since, according to most theories of regeneration, the younger stages should possess greater regenerative power than the older. The results of the first group are as follows:

Experiment 1. A number of larvae, placed on a fowl on May 25th, dropped off gorged on the 29th and 30th, and were kept at a temperature of about 27° C. On June 3rd the second right legs of five of these larvae were amputated and the ticks kept at the same temperature. Two days later. one of these larvae (*a*) moulted and possessed a normally-developed second right leg, with the exception that the tarsus was very imperfect. The other four ticks moulted respectively, two on the third and one on each of the fourth and sixth days after the operation; in none of these was there any trace of regeneration. Since in larva (*a*) only two days had elapsed between the amputation and the moult, it seems probable that the immature nymphal leg had already been formed within the skin of the larval leg and partly withdrawn; therefore the needle had only passed through the tarsus, and this portion of the limb was not regenerated.

Experiment 2. A number of larvae were placed on a fowl on November 3rd and dropped off gorged on the 7th. The same day (Nov. 7th) the second right legs of eleven of the gorged larvae were cut off, in every case the four or five distal articles being removed. These ticks were kept in an incubator supposedly at a temperature of 27° C., but during the experiment the heating apparatus went wrong and for some weeks the temperature varied from 15° C. at night to as much as 35° C. during the daytime. This diurnal variation seems to have had a marked effect on the subsequent development, for although members of the same batch of ticks kept at a constant temperature of 37° C. all became adult after two nymphal stages, in this experiment no less than eight out of the eleven passed through at least three nymphal stages.

Six to ten days after amputation the larvae all moulted to first stage nymphs and in none of them was there any trace of regeneration of the lost appendage. All these ticks were reared through the next two stages, and the results were fairly uniform. In every case, when the animal moulted to the second stage nymph, the second right leg was regenerated. The regenerated appendage was perfectly formed but was slightly smaller than the corresponding appendage of the opposite side. After the next moult, the size of the regenerated limb was practically normal.

Experiment 3. Eleven gorged larvae from the same batch as those used in the preceding experiment had their legs amputated on Nov. 7. In each case, as before, the second right leg was removed between the second and third articles. The ticks were kept at a constant temperature of 37° C. Four days later (Nov. 11) nine moulted, none of them showing any regeneration. The following day (Nov. 12) the remaining two moulted. In one of these there was no regeneration, but in the other the animal had regenerated a short rod-like appendage indistinctly divided into three articles.

All these ticks were raised to the adult state and, apart from the above-mentioned exception, the legs regenerated at the next moult and were perfectly formed, but slightly smaller than those of the other side. The abnormal example however, which had already commenced to regenerate previous to the first moult, after the second, regenerated a limb perfect both in size and form.

After the final moult, the regenerated appendages of all the ticks were practically perfect.

A series of controls kept under identically the same conditions showed that amputation had no marked effect on the duration of the stages.

Experiment 4. In this series the legs of twenty-two gorged larvae were amputated the day they dropped off the fowl and kept at 37° C. Four to five days later they all moulted and in no case was there any trace of regeneration. These first stage nymphs were allowed to remain without another feed in order to see whether the absence of a limb would stimulate the animals to proceed to another moult, but they all died without proceeding to another stage.

Experiment 5. In all the preceding experiments only the second right leg had been removed and therefore we sought to determine if the removal of other limbs gave corresponding results. The larvae used in this series were all put on a fowl on April 5 and dropped off gorged five days later. After amputation some of these larvae were kept at 37° C. and others at 30° C. For the sake of convenience the results are presented in tabular form.

(*a*) Larvae kept at 30° C.

i. First right leg amputated 10. IV. 13:

16. IV. 13	9 moulted	No regeneration.
17. IV. 13	3 ,,	,,

ii. Second right leg amputated 10. IV. 13:

17. IV. 13	8 moulted	No regeneration.
18. IV. 13	4 ,,	,,

iii. Third right leg amputated, 10. IV. 13:

16. IV. 13	5 moulted	No regeneration.
17. IV. 13	6 ,,	,,

iv. Hind pair of legs amputated 10. IV. 13:

16. IV. 13	2 moulted	No regeneration.
17. IV. 13	6 ,,	,,
18. IV. 13	3 ,,	In two examples, no regeneration; in the third, miniature legs one-third the normal size were present.

v. Two hind pairs of legs amputated 10. IV. 13:

16. IV. 13	7 moulted	No regeneration.
17. IV. 13	5 ,,	,,

vi. All three pairs of legs amputated 10. IV. 13:

17. IV. 13	3 moulted	No regeneration.
18. IV. 13	7 ,,	No regeneration in eight individuals; in two cases a two-jointed knob developed in place of the front legs.

With few exceptions the ticks in this series all moulted without showing any signs of regeneration, and it will be noticed that the period elapsing before moulting is only slightly lengthened in the case of those animals which had lost all their limbs. In all the above series the fourth pairs of nymphal legs appeared as usual and were normal both in size and form.

(*b*) Larvae kept at 37° C.

i. First right leg amputated 10. IV. 13:

14. IV. 13	4 moulted	3, no regeneration; 1, small two-jointed knob regenerated.
15. IV. 13	1 ,,	Small three-jointed rod developed, with miniature claw.

ii. Second right leg amputated 10. iv. 13:

14. iv. 13	1 moulted	No regeneration.
15. iv. 13	4 ,,	2, no regeneration; 2, small pointed knob present.
16. iv. 13	1 ,,	A two-jointed rod present.

iii. Third right leg amputated 10. iv. 13:

14. iv. 13	6 moulted	No regeneration.

iv. Hind pair of legs amputated 10. iv. 13:

14. iv. 13	4 moulted	No regeneration.
15. iv. 13	2 ,,	,,

v. Two hind pairs of legs amputated 10. iv. 13:

15. iv. 13	3 moulted	2, no regeneration; 1, left side, no regeneration: right side, second appendage, three-jointed rod without claw; third appendage, four-jointed rod, with rudimentary claw.
16. iv. 13	2 moulted	In both cases two pairs of half-size legs regenerated, the articulations somewhat indistinct.

vi. All three pairs of legs amputated 10. iv. 13:

14. iv. 13	1 moulted	No regeneration.
	4 dead	
15. iv. 13	1 moulted	No regeneration.

In this latter series more of the ticks showed signs of regeneration than in the case of those kept at 30° C., but the results are not definite enough to permit of conclusions.

In both series examples from each of the experiments were fed and allowed to moult to second stage nymphs. In every case the limbs then regenerated and varied from two-thirds to three-quarters the normal size, but were perfectly proportioned.

In all the above experiments the almost total absence of any attempt at regeneration in the larval stage is very striking, but it might be explained as the result of the comparatively short time elapsing between the amputation and the moult.

We therefore performed a second series of experiments in which we cut off the legs whilst the larvae were still feeding, and as will be seen we obtained quite different results.

Experiment 6. A batch of larvae was put on the fowl on April 5. Three days later some of the legs of sixteen ticks were amputated whilst still on the fowl. Three of these ticks dropped off gorged two days later, whilst the remaining thirteen dropped off the following day. Owing to the difficulty of operation, it was impossible to remove any particular articles and therefore the extent of the amputation could only be determined later and varied considerably in different individuals.

The results are presented in tabular form.

Date when ticks dropped off fowl	Number of ticks	Extent of amputation	Date of moult to first stage nymph	Extent of regeneration
10. iv. 13	1	Legs 2 and 3 of left side	17. iv. 13	No regeneration.
,,	1	3 right legs	,,	First right leg, half-size and imperfect; legs 2 and 3 absent.
,,	1	All 6 legs, with exception of 3 articles on left hind leg	,,	Right side, 3 perfect legs; left side, leg 1, four-jointed stump; legs 2 and 3 absent.
11. iv. 13	3	3 right legs	,,	Perfectly formed limbs, but only three-quarters normal size.
,,	7	3 right legs	18. iv. 13	In five, limbs as above; in one, leg 1 three-quarter size, leg 2 half-size, leg 3 a three-jointed stump, with a small terminal hook (Fig. 1, *B*); in the other, leg 1 half-size, legs 2 and 3 absent.
,,	1	Legs 2 and 3 of right side	19. iv. 13	Legs 1, 2 and 3 all half to two-thirds normal size. (Fig. 1, *A*.)
,,	2	Leg 3 of right side	18. iv. 13	Leg absent—no regeneration.

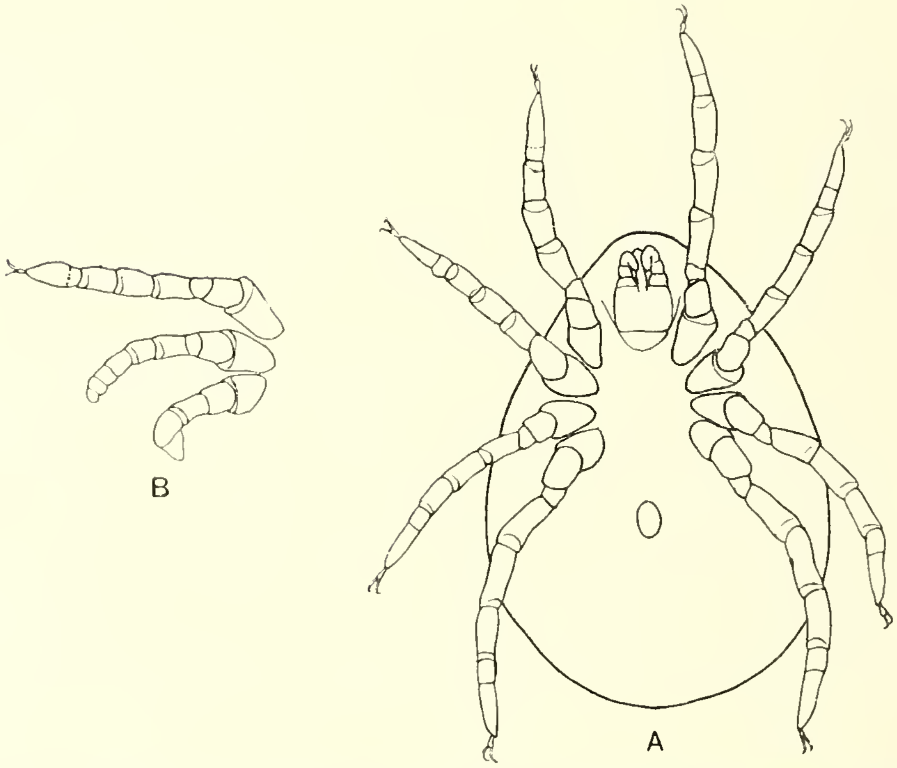

Fig. 1. *Argas persicus*, first stage nymph: (*A*) tick from Experiment 6, showing almost perfect regeneration of the first three right legs; (*B*) first three right legs of another individual from the same experiment, showing imperfect regeneration. (×13.)

From these results it seems that a period of at least nine days must elapse between the amputation and moulting. Even with this period, however, some individuals showed no signs of regeneration, whilst others only developed very imperfect appendages.

We should like to call attention to the case in which, although only the second and third legs of the right side were removed, yet in the nymph the first right leg was reduced in size as well as the regenerated appendages; all the left legs and also the fourth right leg were of normal size.

First Stage Nymphs.

Since all stages of *A. persicus*, excepting the larval stage, usually feed to repletion within half-an-hour, the time between feeding and amputation can be determined exactly, and it will be noticed that the results of this series of experiments are much more uniform than in the case of those with the larvae.

Experiment 7. A batch of first stage nymphs was fed on December 9. The following day the four or five distal articles of the second right leg were removed, the ticks being kept at a uniform temperature of 37° C. At the same time an equal number of the same batch of nymphs were kept as control in order to see whether the amputation delayed the subsequent moulting.

Of the amputated ticks, one moulted on 16. xii. 12, four on 17. xii. 12, and six on 18. xii. 12. In every case, all the articles of the appendage were regenerated and the leg was of normal proportions, but the size was only two-thirds to three-quarters that of the corresponding leg of the opposite side. Of the controls, seven moulted on 16. xii. 12, and four on 17. xii. 12. It seems therefore that amputation may slightly delay the subsequent moulting.

Experiment 8. A batch of first stage nymphs was fed on April 2, and then divided into groups of six, in each of which different legs or different articles were amputated. In every case the ticks were kept at 30° C. The results are given in tabular form.

(*a*) Claws of second right leg amputated 3. iv. 13.

14. iv. 13	2	moulted	Regeneration	perfect.
15. iv. 13	2	,,	,,	,,
17. iv. 13	1	,,	,,	,,
19. iv. 13	1	,,	,,	,,

This experiment was undertaken especially to determine whether the regenerated claw showed any tendency to revert to the larval type, which, in *A. persicus,* differs considerably from the nymphal claw, owing to the presence of a large pulvillus. In no case could we detect any sign of a larval pulvillus on the regenerated claws.

(*b*) First distal article of second right leg amputated 3. iv. 13.

16. iv. 13	1 moulted	Distal article slightly shorter, but same thickness as remainder of leg.
17. iv. 13	1 ,,	Ditto.
18. iv. 13	1 ,,	Ditto.
20. iv. 13	1 ,,	Ditto.
25. iv. 13	1 ,,	Two distal articles shorter than normal.
29. iv. 13	1 ,,	Regeneration almost complete.

As might be expected, no marked differences could be detected between the amputated and the normal legs. In most cases the regenerated tarsus was slightly shorter, but approximately of the same thickness as the corresponding one of the opposite side, and the claws seemed to be normal (Fig. 2, *B*). In one case, however, the penultimate was also shortened.

(*c*) Two distal articles of second right leg amputated 3. iv. 13.

16. iv. 13	2 moulted	Regenerated leg normally jointed, but four distal articles three-quarter size.
19. iv. 13	1 ,,	Ditto.
21. iv. 13	1 ,,	Ditto.
25. iv. 13	1 ,,	Ditto.

The nature and extent of the regeneration were approximately the same in all these cases and will be understood on reference to Fig. 2 (*C*).

It will be noticed that the reduction in size certainly includes articles 4 and 5 and possibly article 3, although only two articles (6 and 7) had been removed.

(*d*) Three distal articles of second right leg amputated 3. iv. 13.

14. iv. 13	1 moulted	Regenerated leg less than half-size and all six distal articles miniature.
15. iv. 13	2 ,,	Nature of regeneration as above, but size varying from half to two-thirds that of normal leg.
19. iv. 13	1 ,,	
20. iv. 13	1 ,,	
27. iv. 13	1 ,,	As above, but leg quite three-quarters normal size.

As in (*c*), reduction took place in articles other than those which had been removed, for although only three distal articles had been amputated, all the articles were distinctly miniature. As might be expected, the longer the interval between amputation and moulting, the greater was the extent of regeneration.

(*e*) Four distal articles of second right leg amputated 3. iv. 13.

16. iv. 13	1 moulted	Regenerated leg about three-quarters normal size; normally jointed; articles down to coxa all reduced in size.
20. iv. 13	2 ,,	
24. iv. 13	1 ,,	
30. iv. 13	1 ,,	Regenerated leg only very slightly smaller than normal.
1. v. 13	1 ,,	

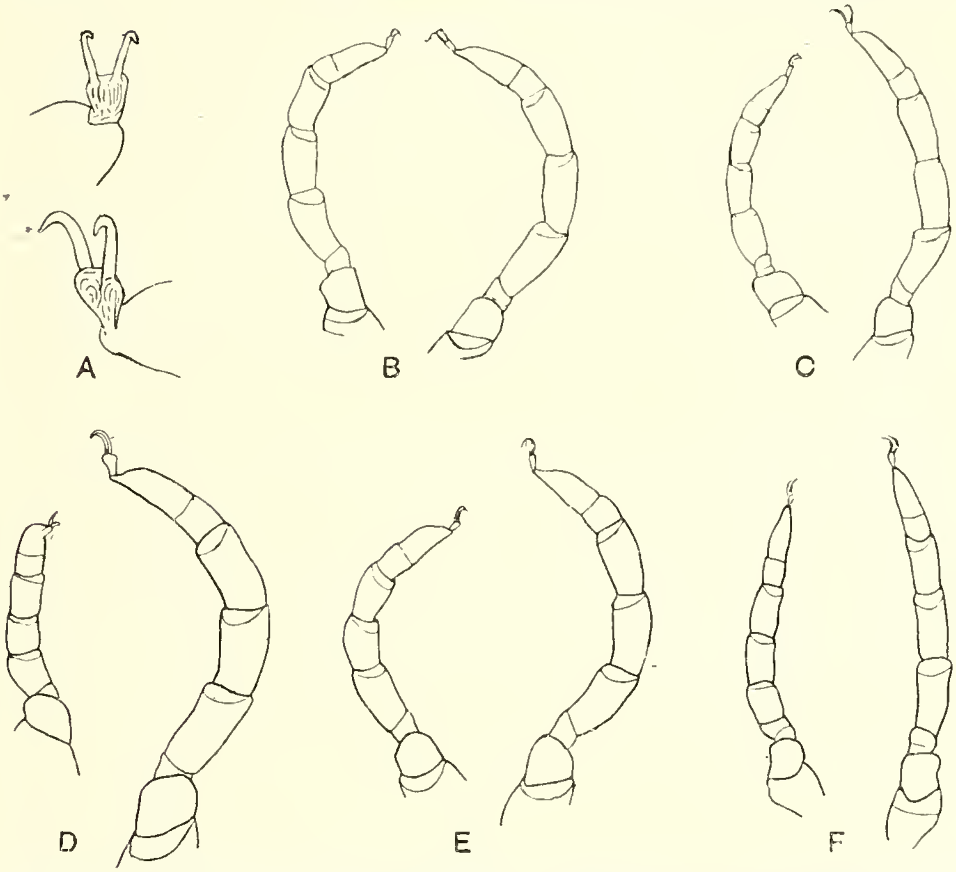

Fig. 2. *Argas persicus*, second stage nymph from Experiment 8, showing regeneration after removal respectively of—(*A*) claw, (*B*) tarsus, and (*C*) two, (*D*) three, (*E*) four and (*F*) five distal articles of second right leg. In every case the corresponding appendage of the opposite side is shown. (*D*) represents an abnormal type of regeneration. Magnifications: *A*, *B*, *C*, *E*, *F* × 22; *D* × 33.

On comparing the results of this experiment with those of the preceding (*d*), although an additional article was removed in (*e*), yet we find that the extent of regeneration in the latter case is distinctly greater (Fig. 2, *E*).

(*f*) Five distal articles of second right leg amputated 3. iv. 13.

13. iv. 13	1 moulted	Regenerated leg less than half normal size; normally jointed; articles down to coxa all reduced.
14. iv. 13	2 ,,	
18. iv. 13	1 ,,	As above, but size of limb about three-quarters normal size.
20. iv. 13	1 ,,	
28. iv. 13	1 ,,	Ditto, but two-thirds normal size.

The small extent of the regeneration in the first three ticks is noteworthy, but is explicable on the comparatively short time elapsing between amputation and moulting (Fig. 2, *F*).

(*g*, *h*, *i*, *k*) In this series, the first, second, third and fourth right legs respectively were amputated on 3. IV. 13.

The results were uniform; in every case the regenerated appendage was normally jointed but only about three-quarters the size of the corresponding leg on the opposite side. The regenerative power possessed by each limb seems to be approximately the same.

(*l*, *m*, *n*, *o*) In this series, respectively the fourth pair, the third and fourth pairs, the three hind pairs and finally all the legs were amputated 3. IV. 13. The results were uniform; even in those individuals which had lost all their legs, normally jointed limbs were regenerated, but their size varied from two-thirds to three-quarters that of the normal limbs.

Experiment 9. The results of Exp. 8, (*c*) to (*f*), show that no matter how many articles are removed, the regenerated limb is always normally proportioned but reduced in size; in other words, not only those articles which have been removed, but also the remaining articles, partake in the general reduction that ensues. This seemed of such importance that we performed a more extensive series of experiments with larger numbers of ticks. In one batch of nymphs, only the two distal articles were removed, whilst in the other the leg was cut off as near to the coxa as possible. Again we obtained results which thoroughly confirmed our previous observations. In every case the leg regenerated as a whole, not merely renewing the missing articles. Perhaps the regenerated legs were slightly smaller in the case of those ticks which had had more articles removed, but the differences were very insignificant and generally the legs appeared to be of about the size.

Experiment 10. As the period elapsing between feeding and moulting is so important in the larval stage, we tried to determine whether it was equally so in the case of the nymphs. With this object, on 2. IV. 13, a number of first stage nymphs were allowed to engorge themselves and on 4. IV. 13, and each successive day up to 11. IV. 13, the second right legs of a certain number of individuals were removed. As in many cases the moulting was unaccountably delayed, it is necessary, for a clear understanding of the significance of each example, to give the number of days elapsing between feeding and amputation, and between amputation and moulting.

For the sake of convenience we shall refer to these periods as the *pre-* and *post-amputation* periods respectively.

Date of amputation	Date of moult	Number of individuals	Pre-amputation period	Post-amputation period	Nature of regeneration
4. iv. 13	16. iv. 13	3	2	12	$\frac{2}{3}$–$\frac{3}{4}$ miniature.
,,	17. iv. 13	1	2	13	$\frac{3}{4}$,,
,,	22. iv. 13	1	2	18	,, ,,
,,	29. iv. 13	1	2	25	,, ,,
5. iv. 13	16. iv. 13	1	3	11	$\frac{2}{3}$ miniature, leg rather thin.
,,	17. iv. 13	2	3	12	$\frac{2}{3}$–$\frac{3}{4}$ miniature.
,,	19. iv. 13	1	3	14	,, ,,
6. iv. 13	16. iv. 13	1	4	10	$\frac{3}{4}$,,
,,	18. iv. 13	1	4	12	,, ,,
,,	20. iv. 13	1	4	14	,, ,,
,,	24. iv. 13	1	4	18	,, ,,
,,	29. iv. 13	1	4	23	,, ,,
,,	30. iv. 13	1	4	24	,, ,,
7. iv. 13	15. iv. 13	1	5	8	Three-jointed stump, with knobbed end.
,,	17. iv. 13	1	5	10	$\frac{2}{3}$ miniature.
,,	18. iv. 13	2	5	11	$\frac{3}{4}$,,
,,	19. iv. 13	1	5	12	$\frac{1}{2}$,,
,,	25. iv. 13	1	5	18	$\frac{3}{4}$,,
8. iv. 13	15. iv. 13	1	6	7	None.
,,	17. iv. 13	1	6	9	$\frac{1}{3}$ miniature; normal number of articles.
,,	21. iv. 13	2	6	13	$\frac{1}{2}$–$\frac{2}{3}$ miniature.
,,	22. iv. 13	1	6	14	$\frac{2}{3}$,,
,,	23. iv. 13	1	6	15	,, ,,
9. iv. 13	13. iv. 13	1	7	4	None.
,,	18. iv. 13	1	7	9	$\frac{1}{3}$ miniature.
,,	22. iv. 13	1	7	13	$\frac{1}{2}$–$\frac{2}{3}$,,
,,	24. iv. 13	2	7	15	$\frac{2}{3}$,,
,,	26. iv. 13	1	7	17	$\frac{3}{4}$,,
10. iv. 13	13. iv. 13	2	8	3	None.
,,	14. iv. 13	2	8	4	None.
,,	23. iv. 13	1	8	13	$\frac{3}{4}$ miniature.
,,	26. iv. 13	1	8	16	$\frac{1}{2}$,,
11. iv. 13	13. iv. 13	1	9	2	None.
,,	18. iv. 13	1	9	7	None.
,,	20. iv. 13	1	9	9	$\frac{1}{4}$ miniature.
,,	23. iv. 13	3	9	12	$\frac{2}{3}$,,

It will be seen that the minimum period in which any regeneration occurred was eight days, but in this particular case only a three-jointed stump appeared. The first tick with a regenerated limb having the normal number of articles required a post-amputation period of nine days.

Second Stage Nymphs.

In all cases the ticks used in these experiments had been reared in the laboratory and their history was known exactly. This precaution was very necessary as it is impossible from their appearance alone to distinguish with certainty the various nymphal stages.

Experiment 11. A batch of second stage nymphs[1] was fed on a fowl on 13. I. 13. The following day (14. I. 13) four to five articles were removed from the second right leg of each individual. Some of the ticks were kept at a temperature of 20–30° C., and others at 37° C.

(*a*) Second stage nymphs kept at 20–30° C.

19. I. 13	1 moulted	♂	No regeneration.
30. I. 13	2 ,,	♀ and 3rd ⊙	In every case, the regenerated appendage was about half the normal size, but with the usual number of articles.
5. II. 13	2 ,,	♀ and 3rd ⊙	
6. II. 13	1 ,,	♀	
8. II. 13	1 ,,	♀	
9. II. 13	1 ,,	♂	
10. II. 13	1 ,,	♀	
12. II. 13	4 ,,	♀ and 3 ♂ ♂	
13. II. 13	1 ,,	♀	
17. II. 13	1 ,,	♂	
1. III. 13	1 ,,	♂	

(*b*) Second stage nymphs kept at 37° C.

23. I. 13	2 moulted	♂ and 3rd ⊙	Regeneration again about half normal size.
24. I. 13	6 ,,	3 ♂ ♂ + 3 ♀ ♀	
25. I. 13	3 ,,	2 ♂ ♂ + 1 ♀	
27. I. 13	5 ,,	1 ♂ + 3 ♀ ♀ + 3rd ⊙	

It will be noticed that in one case there was no regeneration, but as this animal moulted within five days after the amputation, it is probable that the formative substance of the adult limb had been removed.

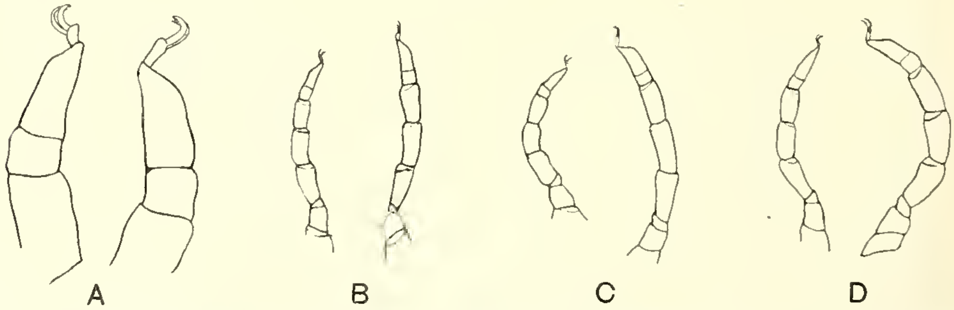

Fig. 3. *Argas persicus*, third stage nymph from Experiment 12, showing regeneration after removal respectively of—(*A*) tarsus, and (*B*) two, (*C*) three and (*D*) five distal articles of second right leg. *A* × 33; *B*, *C*, *D* × 13.

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[1] The sign ⊙ denotes nymph throughout.

Experiment 12. As in the case of the first stage nymph, we performed a series of experiments in order to determine whether the regenerative power varied in different appendages, and also after the removal of different articles.

A batch of second stage nymphs was fed on May 5 and the gorged ticks amputated in various ways on the following day.

(*a*) Tarsus of second right leg amputated 6. v. 13.

20. v. 13	2 moulted	2☉	As a rule the three distal articles of the regenerated limb distinctly shortened and whole leg slightly reduced.
21. v. 13	1 ,,	☉	
22. v. 13	2 ,,	♂ + ☉	
24. v. 13	1 ,,	♀	

(*b*) Two distal articles of second right leg amputated 6. v. 13.

21. v. 13	3 moulted	♂ + ♀ + ☉	In all cases the regenerated leg was approximately two-thirds normal size; all articles reduced in size.
22. v. 13	2 ,,	♂ + ♂	
23. v. 13	1 ,,	♀	

(*c*) Three distal articles of second right leg amputated 6. v. 13.

20. v. 13	1 moulted	☉	The regeneration was of the same type as that in (*b*).
22. v. 13	1 ,,	☉	
23. v. 13	1 ,,	♂	
24. v. 13	3 ,,	3♀♀	

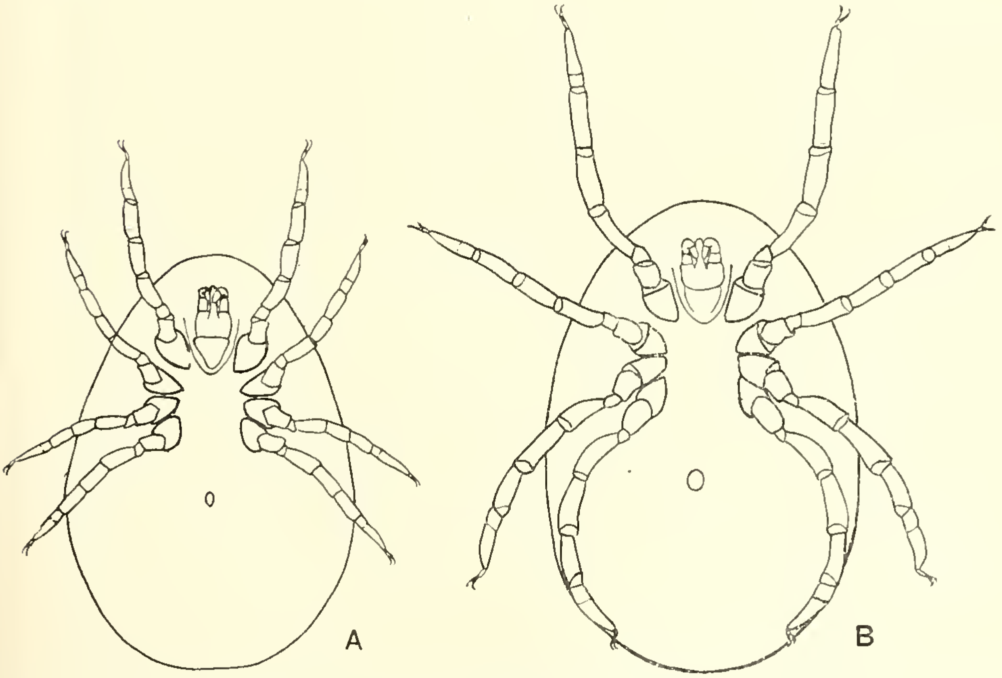

Fig. 4. *Argas persicus*; (*A*) third stage nymph from Experiment 12 (*e*), showing regeneration after removal of all the appendages; (*B*) normal tick for comparison. (× 13.)

(*d*) Four distal articles of second right leg amputated 6. v. 13.

23. v. 13	5 moulted	2 ♂ ♂ + 3 ♀ ♀	Regeneration as in (*b*).
24. v. 13	1 ,,	♂	

(*e*) All legs amputated 6. v. 13.

27. v. 13	2 moulted	2 ♂ ♂	In every case the legs were regenerated with the normal number of articles, but were about two-thirds to three-quarters normal size.
28. v. 13	1 ,,	⊙	
29. v. 13	1 ,,	♂	
31. v. 13	1 ,,	⊙	

In addition to the above, a few experiments were undertaken in order to find out the minimum time in which second stage nymphs could regenerate their limbs. Owing to lack of material we have been unable to carry out these experiments as completely as we should have wished, but the results obtained were concordant with those obtained with the first stage nymphs.

Summary of results.

In all stages of *Argas persicus*, if the leg is amputated sufficiently long before moulting, regeneration takes place, but the regenerated appendage is practically always less than normal in size, although possessing the usual number of articles. In no case was there any evidence of atavistic regeneration. Moreover, when the legs of a larva were amputated it invariably regenerated nymphal legs.

On comparing the periods elapsing between feeding and amputation, and amputation and moulting, respectively, it will be found that in each stage there is a minimum post-amputation period, beyond which no regeneration takes place. It is rather curious that this period is relatively longer in the case of the larvae than in the other stages.

It should be noticed that amputation of one or two articles causes a reduction in all the remaining articles of the leg. The results were very striking in the experiments with the first stage nymphs, in which we amputated respectively one, two, three, four and five articles, yet in all these cases the regenerated limb was normally proportioned though reduced in size.

We must except from these conclusions those cases in which the appendages were amputated about the end of the pre-amputation period. In these examples the regenerated appendages were frequently much reduced in size and also in the number of articles.

Discussion.

It seems impossible to explain the above-described results on Müller's theory that when regeneration takes place the new portion takes on an atavistic form. This theory was based on his observation (Fritz Müller, 1880) that when the chelae of the Brazilian shrimp, *Atyoida potimirim*, a long clawed form, were amputated, the regenerated limb reverted to the short clawed type of the related genus *Caridina*, the latter genus being phylogenetically older than *Atyoida*.

Similarly Giard (1897) and Bordage (1897–1900) noted that when the tarsus of a pentamerous insect was removed, it regenerated a tetramerous appendage. They considered this as a reversion to the type of limb in the primitive *Apterygota*, in which group tetramery is found. Bordage, however, in his paper on the tetrameric regeneration of the tarsus of the *Phasmidae*, noticed that sometimes a five-jointed tarsus was regenerated. Similar results were also obtained by Brindley (1897) in the case of the *Blattidae*. These results might be explained on the supposition that the power of regeneration was imperfectly developed, and that the four-jointed tarsi were merely examples of incomplete regeneration. Barfurth, however, showed that when the four-toed anterior appendage of an Axolotl was amputated an atavistic five-toed appendage was regenerated.

On the whole we think our results could be best explained by adopting Bonnet's idea of specific substances flowing in definite directions. The hypothesis with some modifications has been applied by Sachs and also Goebel to explain regeneration in plants, and both Loeb and Driesch have also used the same idea to explain the regeneration of *Tubularia*. In this polyp there is present in the hydranth and stem a red pigment in the form of granules in the endodermal cells. This pigment is concentrated in that part of the stem adjoining the hydranth. If a piece of the stem is cut off, it closes its cut ends and in the central cavity a circulation of fluid begins. Globules containing the red pigment granules now appear in this fluid. In the course of twenty hours the new hydranth begins to appear near one end of the stem and in this region the granules are reconcentrated, disappearing from the circulation.

Similarly, we suppose that formative substances are contained in the body of the tick. During the period of growth these substances are continually being distributed to their specific localities in the body.

Thus, the formative substance for the second tarsal claw, during growth periods, is continually passing to that part of the animal, and in the case of the larva the rudiments of the nymphal claw are similarly being deposited. These formative substances might be supposed to be stimulative in their action, merely directing the construction of the nutritive substances into the specific parts of the organism.

We may assume that the amount of nutriment supplied to each part of the body is constant. Accordingly, when two articles of a leg are removed, during the regeneration called forth by the continued deposition of formative substances, food material is used up which ordinarily would have been available for the other articles and only after the missing parts have been replaced can any further growth of the whole limb take place. This would explain the reduction in size of all the articles of the leg even when only one or two distal articles are removed.

The deposition of formative substances seems to cease some time before the animal moults, and beyond this point no regeneration can take place, even though plenty of food material may be available. In the case of the larva, the deposition of stimulative material usually stops before the animal has finished feeding, and as a result no regeneration takes place even when the legs are amputated immediately after the tick has become fully gorged and plenty of food material is available. In the nymphs the deposition ceases at a point about midway between feeding and moulting. This period we have arbitrarily referred to as the pre-amputation period. The extraordinarily short pre-amputation period in the larva suggests that *Argas persicus* is gradually suppressing its free, active larval stage and that most of the formative substance of the nymphal legs is deposited before the larva hatches from the egg. An almost complete suppression of the free larval stage occurs in two other members of the Argasidae, *Ornithodorus savignyi* and *O. moubata*. In the former the larva emerges from the egg and has some (although very slight) power of movement. In the latter species, however, the suppression is carried further; the majority, though not all, of these larvae emerge from the egg-shell, but all are without power of movement. Further, the larvae of both these species pass to the first nymphal stage without feeding.

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RHIPICEPHALUS SANGUINEUS: VARIATION IN SIZE AND STRUCTURE DUE TO NUTRITION.

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(With 4 Text-figures.)

Prof. Nuttall has suggested that I should continue his investigations (1913) on variation in size and structure due to nutrition, using other species of *Rhipicephalus* and species of other genera.

The variation in size obtained with *Rhipicephalus sanguineus*, the species used in this experiment, was not as pronounced as that recorded in the experiment dealing with *Rhipicephalus appendiculatus*, owing probably to the great mortality in both fully gorged individuals and those which had been removed from the host whilst only partially gorged. The only larvae available had been kept three months, and the majority were in a weakened condition; as in other raising experiments the yields from larvae of a similar age have been poor.

However, an examination of the material successfully raised clearly showed that the structural variation produced by malnutrition in *Rhipicephalus appendiculatus* is produced similarly in this species of *Rhipicephalus*, the results of the two experiments being practically identical. Hence it will only be necessary to give the experimental details and summaries of the measurements and points of structural difference between the normal and ill-nourished individuals of the nymphal and adult stages. In order to make this series of experiments as uniform as possible, it has been considered advisable to present the results on the plan of Professor Nuttall's paper.

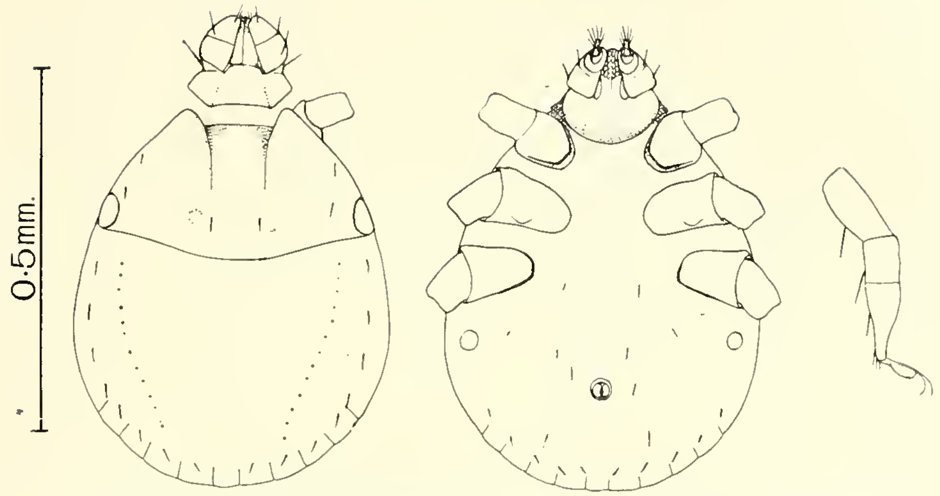

Fig. 1. *Rhipicephalus sanguineus*, unfed larva: dorsal and ventral aspects, and tarsus 3. No. 1932 (8). N. C. del.

Unfed larvae, the progeny of a single female, were placed on a rabbit[1], 8. IV. 13.

A. 288 partly gorged larvae were picked off between the 3rd and 15th days; nymphs emerged on 19. IV. 13, metamorphosis lasting 8 days[2], and were placed on the rabbit on 24. V. 13.

C. 26 nymphs, partly gorged, were picked off between the 4th & 10th days; adults emerged on 9. VI. 13, metamorphosis lasting 12 days. Set I.

D. 11 nymphs, fully gorged, dropped off between the 5th & 15th days; adults emerged on 11. VI. 13, metamorphosis lasting 13 days. Set II.

B. 527 fully gorged larvae dropped off the rabbit between the 2nd and 28th days; nymphs emerged on 18. IV. 13, metamorphosis lasting 8 days, and were placed on the rabbit on 13. VI. 13.

E. 13 nymphs, partly gorged, were picked off between the 5th & 12th days; adults emerged on 1. VII. 13, metamorphosis lasting 13 days. Set III.

F. 11 nymphs, fully gorged, dropped off between the 5th & 8th days; adults emerged on 2. VII. 13, metamorphosis lasting 14 days. Set IV.

Variation in Nymphs. Fig. 2.

The measurements of the nymphal scuta were taken and are recorded below. In each case the extreme examples were picked out and examined.

The length of the scutum of the smallest nymph in Set A is only 83 % of that of the smallest in Set B. The scutum of the largest nymph in Set A is approximately as long as that of the smallest nymph in Set B. At the same time, it should be noted that the normal variability in Set B is considerable, the smallest nymph having a scutum only 85 °/₀ as long as that of the largest nymph in the same set.

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[1] The rabbit was kept in a cage in the laboratory of which the average temperature was about 16° C., and the ticks, during metamorphosis, in an incubator maintained at 30° C.

[2] In each case, only the minimum period required for metamorphosis is mentioned.

Measurement in mm. of scuta of unfed nymphs which emerged:

A, from partly gorged larvae.

No.	Length	Breadth
1	0·35	0·42
2	0·35	0·43
3	0·35	0·45
4	0·35	0·46
5	0·36	0·38
6	0·38	0·44
7	0·40	0·45
8	0·40	0·46
9	0·40	0·47
Average	0·37	0·44

B, from fully gorged larvae.

No.	Length	Breadth
1	0·42	0·46
2	0·50	0·55
3	0·50	0·56
4	0·51	0·54
5	0·54	0·56
6	0·54	0·58
7	0·54	0·60
8	0·55	0·56
9	0·55	0·58
10	0·56	0·58
Average	0·52	0·56

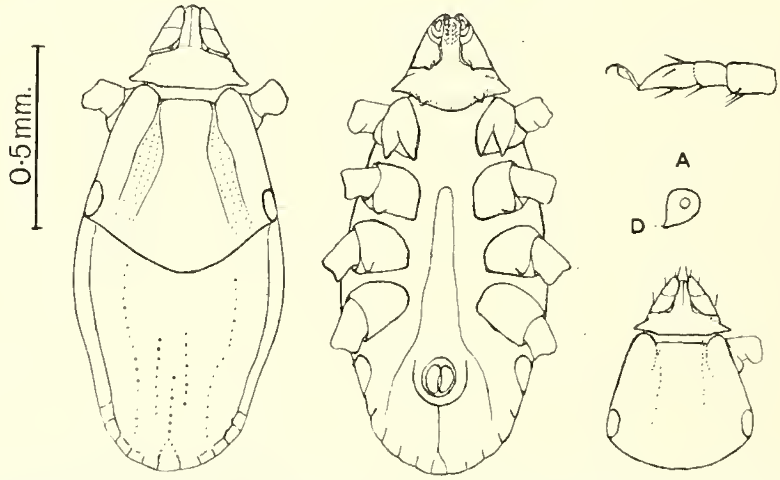

Fig. 2. *Rhipicephalus sanguineus*, nymphs: (1) normally developed unfed individual, dorsal and ventral aspects, spiracle and tarsus 4; (2) capitulum and scutum of nymph which emerged from a partially gorged larva. No. 1932 (8). N. C. del.

Variation in size in adults. Figs. 3 and 4.

Measurement in mm. of scutum of

	Smallest ♂	Largest ♂	Smallest ♀	Largest ♀
Set C. Picked in both larval and nymphal stages	1·20 × 0·70	2·0 × 1·30	0·65 × 0·62	1·0 × 1·10
Set D. Picked in larval stage only ...	2·0 × 1·30	2·50 × 1·60	0·85 × 0·95	1·40 × 1·40
Set E. Picked in nymphal stage only	1·85 × 1·00	2·30 × 1·30	0·80 × 0·80	1·15 × 1·15
Set F. Normal ticks, *i.e.* ticks which were allowed to gorge fully in both larval and nymphal stages	2·30 × 1·50	2·60 × 1·70	1·15 × 1·20	1·30 × 1·35
Normal first cousins to the ticks of above series (smallest and largest individuals of a large progeny from one female).	1·90 × 1·00	2·60 × 1·55	1·20 × 1·10	1·30 × 1·30

Owing to the amount of material in Set F being very small, it was necessary to utilise the progeny of a sister to the female used in the experiment, in order to gain some idea of the normal variation in size.

The largest and smallest males were selected from a large series of *Rhipicephalus sanguineus* received from Africa, and measured. The scuta of the extremes were found to have the following lengths: smallest male 1·6 mm., largest male 3·3 mm. It will be noticed that the variation in size equals that between the smallest tick of Set C and the largest of Set F, experimental animals.

Summary of structural details in which the ill-nourished individuals differ from the normal individuals.

Nymphs[1]. (Fig. 2.) Posterior margin of scutum of dwarf nymph is rounded, and the scutum is proportionately shorter; basis capituli is shorter.

Males. The dwarfs are much less chitinised and of a dark straw colour. The scutum is smoother, less punctate and shows practically no traces of either lateral grooves or dorsal furrows. The palps have no dorsal concavity. The basis capituli is shorter and the posterior cornua are much reduced, the lateral salience being less pronounced. The anal plates are reduced in size, rounded posteriorly, the outer angle of the normal form being absent; they do not project beyond the general body surface. Fig. 3 (*W*) shows a type of anal plate intermediate between those of the male individuals figured. The accessory plates are absent in these dwarf specimens. The tarsi are unarmed and resemble those of the nymph. The extreme variability of the spiracle should be noticed.

In Fig. 3 the extremes are represented by *X* (large male) and *Z* (small male), whilst *Y* represents the spiracle of an intermediate form from the same group (Set C) as the dwarf male. The spiracle of the latter tends to approach that of the nymph.

Females. Posterior margin of scutum rounded (without angularity characteristic of the normal female); cervical grooves and lateral ridges greatly reduced. Tarsi unarmed, resembling those of the nymph.

We have only considered the largest and smallest individuals. They are, however, the extreme examples of regularly graduated series, in

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[1] The difference in lateral salience of the nymphal basis capituli from that of either larva or adult is remarkable, even in the ill-nourished nymphs.

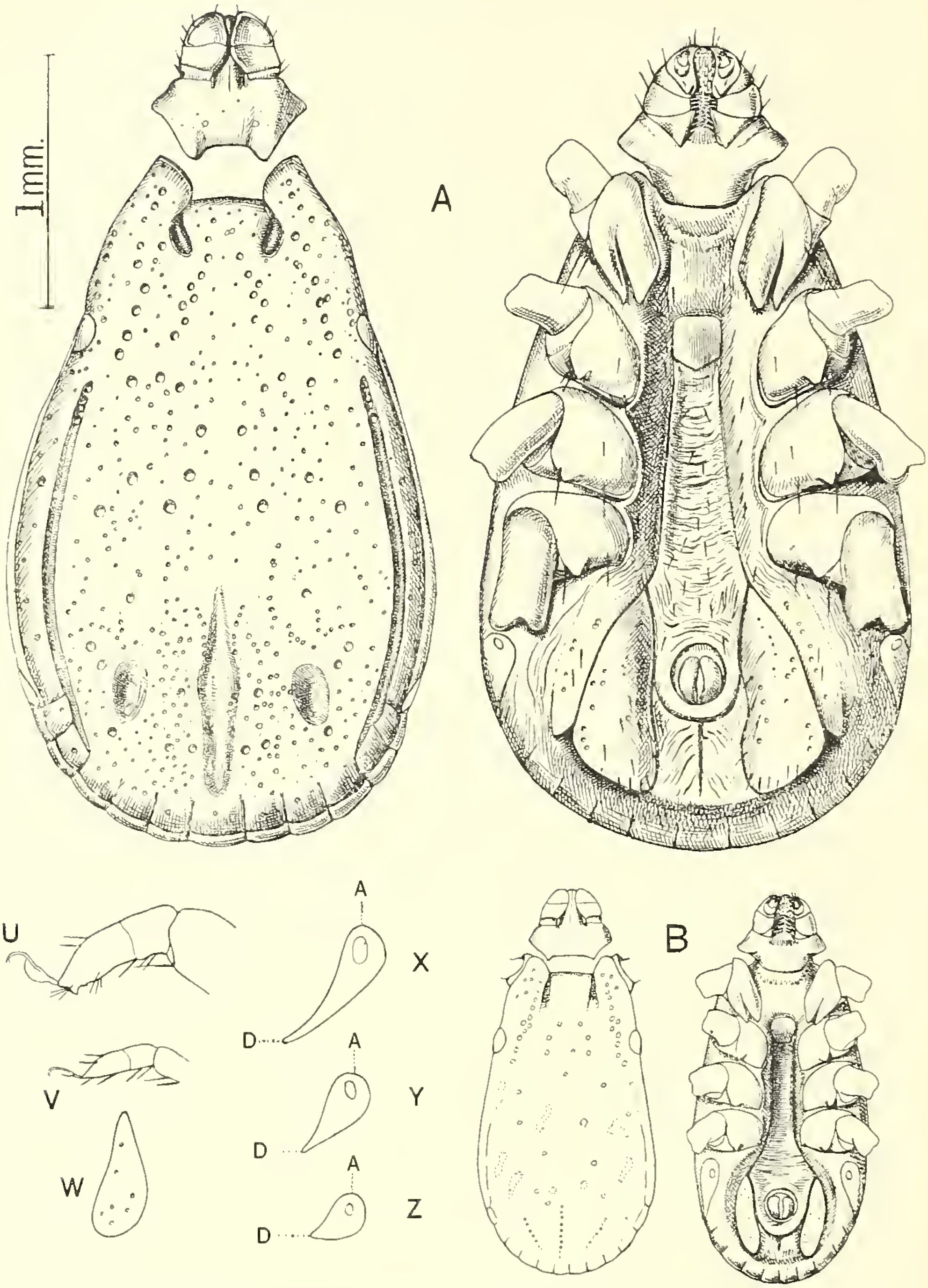

Fig. 3. *Rhipicephalus sanguineus*, males : (*A*) normally developed specimen, dorsal and ventral aspects, (*X*) its spiracle and (*U*) its fourth tarsus ; (*B*) dwarf male, which was picked off the host before it became fully gorged, in both larval and nymphal stages, (*Z*) its spiracle and (*V*) its fourth tarsus ; (*W*) and (*Y*), intermediate forms of anal plate and spiracle respectively. No. 1932 (8). N. C. del.

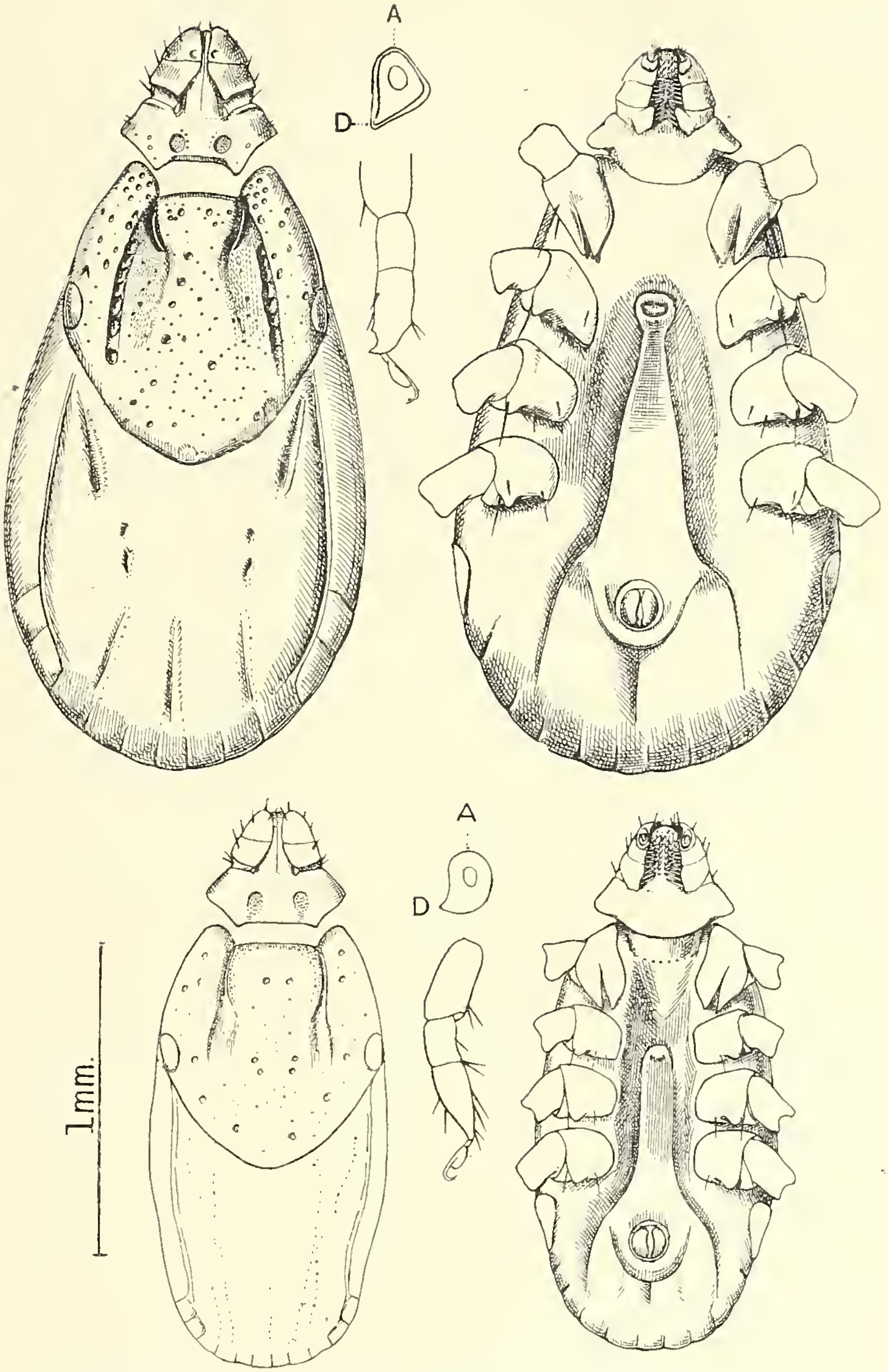

Fig. 4. *Rhipicephalus sanguineus*, females: normally developed specimen, dorsal and ventral aspects, spiracle and tarsus 4; small female, which was picked off the host in both larval and nymphal stages, before it became fully gorged, dorsal and ventral aspects, spiracle and tarsus 4. No. 1932 (8). N. C. del.

which can be traced the growth of the various structural characters mentioned above.

As a similar and equally regular variability is exhibited by the African material, collected in the field, these results again confirm Professor Nuttall's view that variation is due, to a considerable degree, to varying degrees of nutrition.

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OBSERVATIONS ON *ARGAS BRUMPTI*, NEUMANN, 1907.

By NORMAN CUNLIFFE, B.A.,
Student in Medical Entomology.

(*From the Quick Laboratory, University of Cambridge.*)

(With 1 Text-figure.)

In November 1912, through the courtesy of Mr S. W. J. Scholefield, Prof. Nuttall received fourteen living nymphs of *Argas brumpti* from Kitui, British East Africa. As only the adults and later stage nymphs of this species are known, an attempt was made to raise the species in the laboratory.

They were fed on a fowl and usually became engorged within an hour; during metamorphosis they were kept in an incubator maintained at 30° C.

From these nymphs one female emerged on 22. I. 1913 and four males soon after that date. The female was fed on the twelfth and seventeenth days after emergence, but although afterwards placed on a fowl at intervals of twenty days, it refused to feed again until the 143rd day after emergence and it has refused to feed since that date. It was fertilised on the 13th, 70th, 142nd, 158th and 168th days, the males being allowed access to the female twelve days after its emergence.

Eggs were oviposited by the female as follows: 53 eggs between 99–106 days, 66 eggs between 118–125 days, 21 eggs between 152–156 days and 18 eggs between 161–166 days after emergence, making a total of 158 eggs to the present date (4. XI. 13).

The number of eggs in each batch and the intervals between the periods of oviposition varied considerably.

The eggs were kept under varying conditions of temperature and moisture; some were maintained at 23–25° C., others at 30° C. and a few at 37° C., in each case under both dry and moist conditions. Larvae

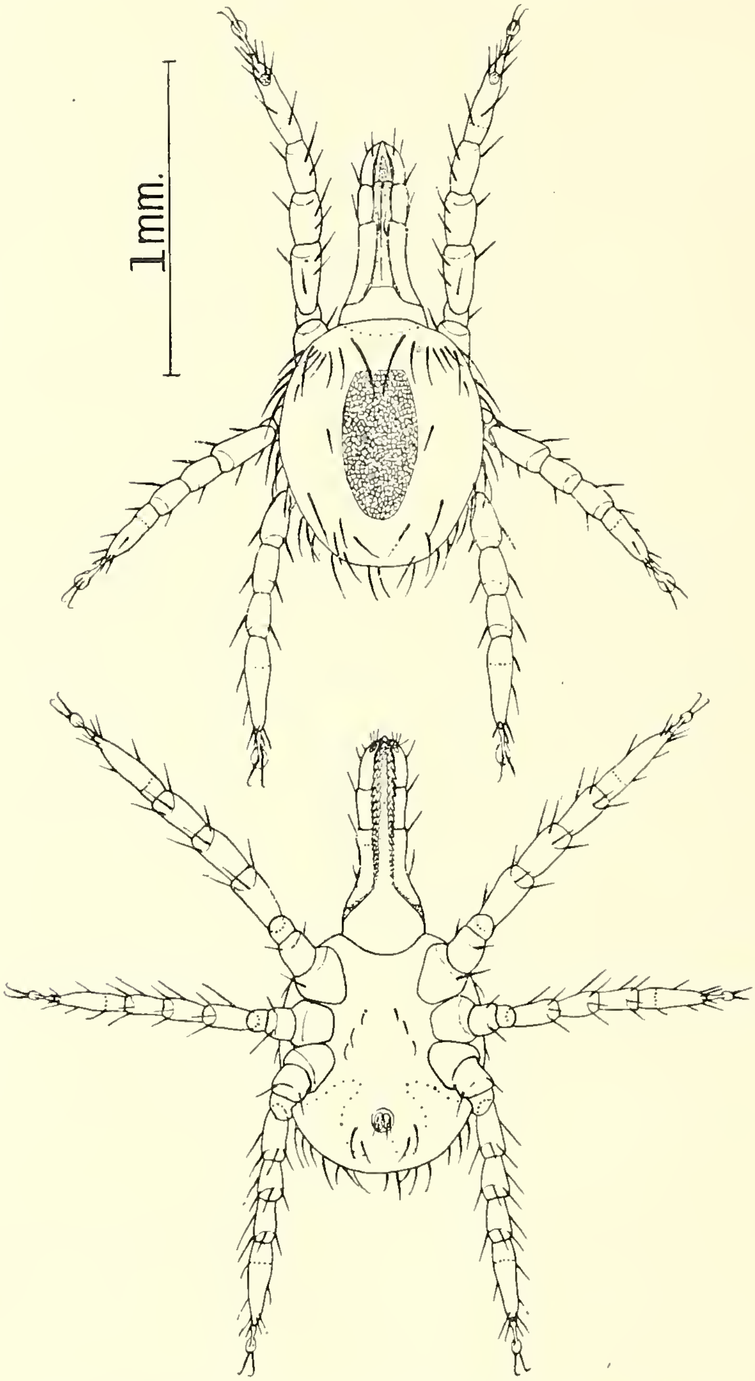

Fig. 1. *Argas brumpti*, larva; dorsal and ventral aspects. No. 1917. N.C. del.

were obtained from only two batches of eggs, namely those oviposited at the periods beginning at the 118th and 161st days respectively; in both cases, the eggs were kept at 30° C. and moistened daily. Nine larvae hatched out from the first batch of eggs after 24–27 days and two larvae from the second batch after 26 days.

It was found impossible, owing probably to the small number available, to raise these larvae through the nymphal stages. Some larvae, although repeatedly placed on a fowl, in some cases for a period of two or three days, nevertheless did not become attached. From these results, it seems doubtful whether the fowl is a suitable host for this tick. In the case of *Argas persicus* the nymphal and adult stages can be reared on several species of birds and also on mammals, but the larvae do not seem to feed on any animal other than the fowl[1].

Egg: pale straw colour, semitranslucent, round or almost round, and ranging in size from 1·0 × 0·8 to 0·7 × 0·6 mm.

Larva (Fig. 1): average size (minus capitulum) 0·8 × 0·65 mm., hexapod, body oval. *Capitulum* exceptionally long, about two-thirds the body-length. Hypostome: dentition 2/2, with about 22 teeth per file. Palps: external border of article I distinctly concave; article III curves ventrally round the hypostome. *Dorsum*: an elongated oval reticulated plate covers the middle of the dorsum. There are prominent pennate body hairs situated marginally.

Legs: anterior pair long and stout, normally carried in the forward position indicated in the figure (dorsal aspect). Coxae I and II contiguous, unlike those of nymph and adult. Pulvillus small (unlike that of larva of *Argas persicus*; the larva climbs glass with difficulty).

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[1] Very little is known regarding the biology of *Argas brumpti*. Nuttall and Warburton (1908) write regarding the habitat of this species: "Dr Brumpt (9. v. 1908) informs us that he found *A. brumpti* in dusty sheltered hollowed out places beneath overhanging calcareous rocks, into which opened porcupine (*Hystrix* sp.) burrows. The ledges of rock were situated along the rocky bed of a torrent, and the floors of the hollows, which were about 5 ft. deep, consisted of fine dust about 15 cm. in depth, numerous bones of small mammalia lying upon it. After *A. brumpti* had fed, it promptly buried itself in the dust. The ticks wander about at night and Dr Brumpt was unable to catch any during the daytime."

In Feb. 1913, Prof. Nuttall received further information concerning the habitat of this tick from Mr S. W. J. Scholefield, who states that he found them in the dust of an antheap when looking for big game, in the Yatta Plains, British East Africa. The natives say it only feeds on large animals: elephant, buffalo, eland and giraffe; and that when it bites man it causes great pain and sickness. The natives call both *A. brumpti* and *O. savignyi* "Kituñu." "*A. brumpti* is said to be always obtainable in the dust where big game roll."

THE ANATOMY OF *ARGAS PERSICUS* (OKEN 1818).

PART III[1].

By L. E. ROBINSON, A.R.C.Sc. Lond.,
and J. DAVIDSON, M.Sc. Liverpool.

(From the Cooper Laboratory for Economic Research, Watford.)

(With Plates XXV to XXVIII and 8 Text-figures.)

The Muscular System.

Plate XXV (see also Part II, Plates XV and XVI).

The muscular system is so highly developed in the *Ixodoidea*, that it is no matter of surprise that it has been the subject of more or less detailed treatment in most of the publications dealing with tick anatomy; but, with a single exception, the existing descriptions do not extend beyond a general classification of the various muscles, with the addition of brief remarks, in some instances, on the histological structure of the muscle fibres. In the majority of cases, also, the observations only apply to the Ixodid ticks, and although the general arrangement of the musculature in the two families of the *Ixodoidea* is not fundamentally different, the comparative anatomy of the muscles offers some difficulty, owing to the great morphological differences which the two families present.

So long ago as 1858, Heller[2], in his extensive work on the anatomy of *Argas persicus*, observed that the *dorso-ventral body muscles* present certain differences to the *muscles of the appendages*, and that the muscles of this tick conform to the general rule which obtains in the *Arthropoda*, namely, that they are all, including the visceral muscles, of the *transversely striated* type. Later observers have usually confined their attention to the musculature of the mouth-parts and pharynx, the remainder of the muscular system receiving only casual treatment. A short historical *resumé* of the subject is to be found in Bonnet's work on the comparative anatomy and development of the *Ixodoidea*[1].

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[1] Parts I and II appeared in Nos. 1 and 2 of this volume; pp. 20–48 and pp. 217–256, respectively.

[2] Heller, C. (1858), p. 303.

The exception referred to above, is the work of Nordenskiöld on the histology of the body-muscles of *Ixodes ricinus*[2]. He calls attention to the existence of a most remarkable feature in the structure of the *dorso-ventral body-muscles,* which provides for the relatively great increase in length of these muscle columns necessarily accompanying the process of engorgement. In *Argas persicus,* as might be expected from its different mode of life, this exceptional structure of the body muscles, as seen in *Ixodes,* is entirely absent, or only exists in a modified form and to a limited extent, during those phases of the tick's existence in which histiogenetic changes are following the dissolution of the tissues which precedes each moult.

So far as we have been able to see, the only marked difference between the body-muscles and the muscles of the appendages in *Argas persicus* is that to which Heller calls attention, *viz.* that the former are muscle columns which maintain a practically constant diameter from one extremity to the other, and are inserted into the chitinous integument without the intermedium of a tendon. As will be shown later, the latter difference is unimportant, inasmuch as a careful examination of the insertions of these muscles shows that Heller's view was not strictly correct.

The following description of the histological structure of the muscles of *Argas persicus* applies equally to both the *dorso-ventral body-muscles* and to the *muscles of the appendages.*

Each muscle is composed of a number of parallel fibres, the cross section of which presents a more or less polygonal figure, due to mutual pressure. The fibres are interpenetrated by a delicate connective tissue framework which, on the external surface of the muscle, forms an investing sheath, but is of so flimsy a nature that it does not suffice to hold the muscle fibres together when the surrounding parts are disturbed, with the result that in dissections, the fibres are apt to become widely separated at the torn extremities of the muscles. In sections, also, the component fibres of a muscle are often more or less separated on account of the shrinking of the muscular tissue. Each muscle fibre is closely invested by an exceedingly thin structureless *sarcolemma*, immediately beneath which elongated nuclei are distributed at more or less wide intervals in the superficial *sarcoplasma*. In the ordinary preparations the interior of the muscle fibre generally appears to consist of very fine longitudinally arranged parallel fibrils. In transverse section, the whole interior of the muscle fibre with the exception of a very thin superficial zone is filled with the contractile substance, this being surrounded by a matrix of sarcoplasm which fills in the space between the sarcolemma and the contractile portion, constituting the thin superficial zone referred to above (see Text-fig. 1).

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[1] Bonnet, A. (1907), pp. 96, 97.

[2] Nordenskiöld, E. (1908), p. 670.

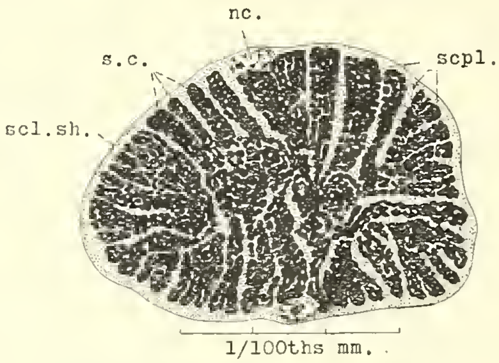

Fig. 1. *Argas persicus* ♀. Transverse section of a muscle fibre (from the retractor muscle of the chelicera). Gilson's fluid; Heidenhain's iron alum haematoxylin and orange G.

nc. nucleus; *s.c.* contractile substance (sarcostyles); *scl.sh.* sarcolemma sheath; *scpl.* sarcoplasm.

Material fixed in Gilson's modification of Carnoy's fluid[1] and stained with Heidenhain's iron alum haematoxylin and orange G. shows the finer structure of the muscle fibres in a most admirable manner. The contractile elements of the fibre retain the basic dye much more persistently than the sarcoplasm, and by careful differentiation with the iron alum solution, the detailed structure is perfectly displayed. In suitably prepared sections, therefore, the contractile substance, being more deeply stained than the sarcoplasm, is readily distinguished. It is then seen to consist of small elements which, in cross section, appear as more or less coherent granules aggregated in clumps, which radiate from the central portion of the muscle fibre. Between these radial masses of the contractile substance, the sarcoplasmatic matrix penetrates. These deeply staining elements of the contractile substance are the *sarcostyles*. The whole arrangement somewhat resembles the structure of the thoracic muscle fibres of some insects. The nuclei of the muscle fibre, as already mentioned, are situated in the superficial sarcoplasm immediately beneath the sarcolemma. They are generally much elongated in the longitudinal direction of the fibre, are relatively poor in chromatin and each contains a single nucleolus. So far as we have observed, the sarcoplasm of normal muscles shows no cellular division such as Nordenskiöld has described in *Ixodes ricinus*, nor does the sarcoplasm attain any degree of thickness on the surface of the contractile substance. In certain phases of development, however, we have seen appearances which resemble to a certain degree those observed by Nordenskiöld in the normal body-muscle fibres of *Ixodes*[1], but these appearances were, without doubt, due to histiogenetic phenomena. They were confined to the regenerating muscular tissue which is always in evidence in the phase accompanying a moulting period.

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[1] See Lee, A. Bolles, *The Microtomist's Vade-Mecum*, 5th ed., J. and A. Churchill, London, p. 64.

This difference between *Argas* and *Ixodes* is explained by the fact that after engorgement, the body-muscles of the former do not undergo any material increase in length, while in the latter, the distention of the body is relatively so enormous, that unless special provision were made for the elongation of the dorso-ventral body-muscles, these would rupture under the strain. The slow rate of engorgement of the Ixodid ticks allows ample time for the elongation of the muscle fibres either by actual growth, or, as Nordenskiöld suggests, by extension of the sarcoplasm cells[2].

Almost at the points of attachment of the dorso-ventral body-muscles, at either extremity, to the chitinous cuticle, the contractile substance terminates, and the sarcolemma sheath runs out into a number of slender tapering tendinous fibrils which penetrate between the hypodermal cells and enter the substance of the chitinous cuticle, into which they pass for some distance and ultimately disappear. In the case of the muscles of the appendages, the basal attachments to the body cuticle appear to be identical with those of the dorso-ventral body-muscles, but at the other extremity, each muscle is continued for a longer or shorter distance as a single tendon.

The integumental discs, as mentioned in Part I of this work (pp. 29–30), mark externally the sites of attachment of the muscles, both the dorso-ventral body-muscles and, as will be seen later, certain of the muscles of the appendages, which originate from the general integument of the body. In the Ixodid ticks their place is taken by the well-known *integumental grooves.* The arrangement of the discs is defined absolutely by the muscular system, just as Dönitz has shown[1] to be the case

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[1] Nordenskiöld, E. (1908), p. 669.

[2] Nordenskiöld, E. (1908), p. 670.

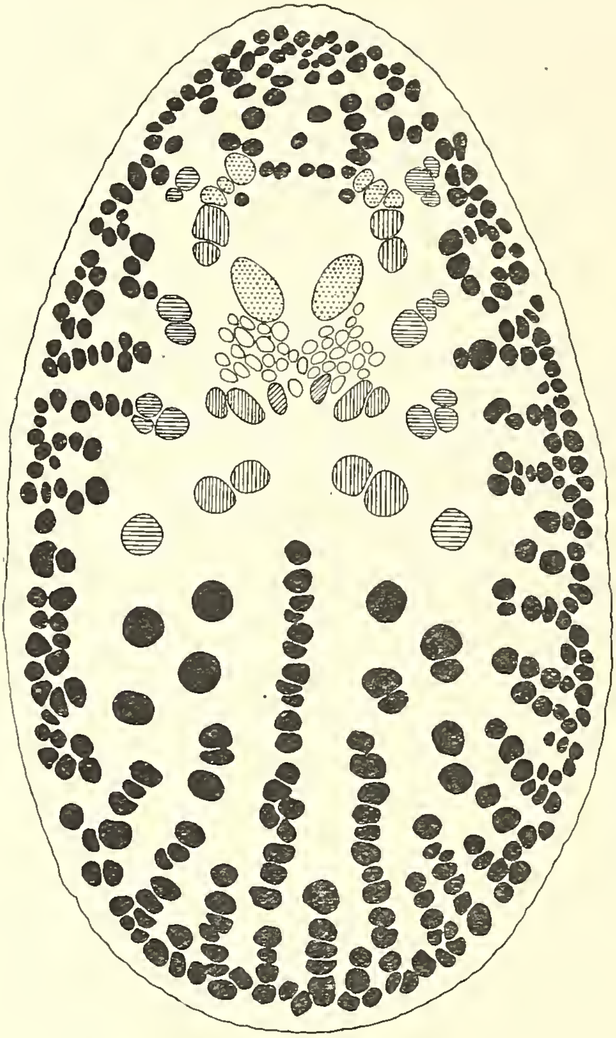

Fig. 2.

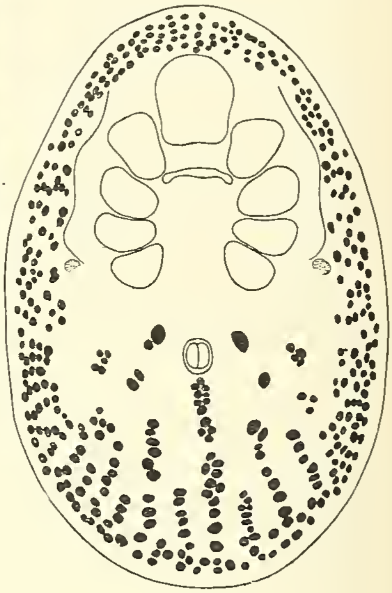

Fig. 3.

Fig. 2. *Argas persicus* ♀. Diagram showing the distribution and muscle relationship of the discs, on the dorsal surface of the body. The associations of the discs with their corresponding muscles are indicated by the various shadings—marginal, postero-median and postero-accessory dorso-ventral body-muscles—*black*; abductors of the coxae—*horizontal* line shading; adductors of the coxae—*vertical* line shading; dorso-genital muscles—*inclined* line shading; depressor and levator muscles of the capitulum—*stippled* shading; retractor muscles of the chelicerae—*white.*

Fig. 3. *Argas persicus* ♀. Diagram showing distribution of the discs on the ventral surface of the body.

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[1] Dönitz, W. (1909), pp. 440–442.

with the integumental grooves of the Ixodid ticks and also, to a certain extent, the markings on the scutum of ornate species.

The most cursory examination of the arrangement of the discs on the dorsum of *Argas persicus* enables the observer to recognise the relationship between certain rows of discs and the corresponding grooves of the Ixodid ticks (see Text-fig. 2). A *postero-median* row of discs represents the postero-median groove and a pair of adjacent shorter rows occupy the position of the *accessory* grooves. In order to clearly recognise the homologies of the remaining discs with the integumental grooves of the *Ixodidae*, some knowledge of their relations with the underlying muscles is necessary and it will be more convenient, therefore, to consider the distribution of the discs at the same time as their corresponding muscles are under review.

For convenience in description, the musculature may be classified as follows:

(*a*) The Body-Muscles.
(*b*) The Muscles of the Appendages.
(*c*) The Muscles of the Alimentary Canal.
(*d*) The Muscles of the Genitalia.

(*a*) The Body-Muscles.

With certain exceptions to be mentioned later, the body-muscles are columnar strands, which pass directly in a vertical direction, or in some cases with a slight degree of inclination, through the body-cavity, their upper and lower extremities being inserted into the dorsal and the ventral integument respectively. In their course through the body-cavity, they pass through the notches formed by the alimentary coeca and their terminal sacculations. They are disposed in a regular manner, many of them forming more or less regular rows of variable length and as their upper extremities, and in most cases the lower extremities also, are attached to the internal surfaces of the integumental discs, the arrangement of the latter is determined absolutely by the body musculature. By their contractions, the *dorso-ventral body-muscles* approximate the body walls, thus bringing pressure to bear on the contents of the body-cavity. In this manner, they serve many purposes, among which may be mentioned the following:—

They facilitate the circulation of the coelomic fluid; they assist in forcing the ingested blood into the marginal terminations of the alimentary coeca; they serve to expel waste air from the tracheal system the act of defaecation, the extrusion of ova in the female and spermatophores in the male, and of the glandular secretions—all these functions call in the aid of the body-muscles.

For the most part, the dorso-ventral body-muscles occupy the marginal regions of the body, where their presence is indicated externally by the *marginal discs* present on both the upper and lower surfaces of the body. The general direction of the rows radiates from the central point of the body as is clearly shown in the figures (see Text-figs. 2 and 3).

The *marginal dorso-ventral muscles* (*m.mg.*) extend round the whole circumference of the body, their arrangement being more or less irregular in the anterior and lateral regions, but forming fairly regular rows in the posterior region. From their relations, it is evident that they correspond to the muscles which form the marginal grooves and the festoons of the Ixodid ticks. In their course through the body-cavity they pass between the terminal sacculations of the alimentary coeca.

The *postero-median dorso-ventral muscles* (*m.p.m.*) form a longitudinal series, which extends from the anus to the mid-point of the posterior margin of the body. They form a median partition in the posterior half of the body, which separates the postero-lateral alimentary coeca and the diverticula of the rectal sac. The *postero-accessory muscles* (*m.p.a.*) commence at a point on either side of, and posterior to, the anus, from which they run backwards and terminate some little distance from the body margin. At the anterior end of the series, the muscle columns are generally aggregated into a cluster, a condition which is further developed in the genus *Ornithodorus*. These muscles correspond to the similarly situated muscles of the *Ixodidae* which form the *postero-median* and the *postero-accessory grooves*.

The *camerostomal muscles* (*m. cam.*) take their origin in the dorsal integument, anterior to, and on either side of, the part which overlies the capitulum; their function, in all probability, is to facilitate the exposure of the capitulum during the operation of feeding, by retracting the camerostomal folds into which their lower extremities are inserted.

The *spiracular muscles* (omitted in Plate XXV) each consist of a single thin slip, the upper end of which is attached to the dorsal integument, the lower extremity being attached by a short tendinous insertion into the wall of the atrial chamber.

The *dorso-genital muscles* (*m.gen′.*) originate on the dorsal integument and are inserted at their lower extremities into the ventral body wall, but on account of their close relationship with the genital canal, their description is deferred to the section dealing with the genital muscles.

The remaining body-muscles differ from the foregoing in the fact that they are not connected in any way with the dorsal integument. They form two series—the *subcoxal muscles* and the *intercoxal muscles.*

The *superior subcoxal muscles* (*m. sub. cx. s.*) form a broad band of parallel bundles which run transversely across the floor of the body-cavity on either side of the median line, immediately posterior to the last pair of coxae and the spiracles. The inner extremities of the muscle bundles are attached to the ridge in the ventral integument formed by the coxal fold, and their outer extremities are inserted along the posterior portion of the supracoxal fold.

The *inferior subcoxal muscles* (*m. sub. cx. i*) are composed of bundles of much shorter length than the preceding, which bridge across the depression of the ventral body wall formed by the coxal folds. The series commences at the level of the third pair of coxae and extends backwards for some distance beneath the superior subcoxal muscles.

The *intercoxal muscles* form two groups—the *lateral* and the *mesial.* The *lateral intercoxal muscles* (*m. l. int. cx.* 1 and 2), two in number on either side, connect the supracoxal fold with the first and second coxal interspaces respectively. The *mesial intercoxal* (*m. m. int. cx.* 1–2) *muscles* are attached at their inner extremities to a centrally situated chitinous plate—the *endosternite*—from the lateral margins of which, five slips of muscle diverge. Of these, the first passes to the interspace between the basis capituli and the first pair of coxae, the second, third and fourth are inserted into the three coxal interspaces respectively, and the fifth finds its distal attachment on the posterior margin of coxa 4.

(*b*) The Muscles of the Appendages.

These include the muscles of the capitulum and those of the legs.

Two pairs of muscles are attached to the basis capituli. The *depressor muscles of the capitulum* (*m. d. c.*) consist of two stout bundles which originate from a pair of conspicuous integumental discs of large size and elliptical contour situated at the level of the anterior fourth of the dorsal surface of the body (see Text-fig. 2). From their points of origin, each muscle passes downwards and forwards and is inserted into the lateral portion of the postero-ventral margin of the basis capituli. The second pair, the *levator muscles* (*m. l. c.*) of the capitulum, are somewhat smaller than the preceding; they originate from one of a series of discs which runs forwards on the dorsal surface towards the anterior margin of the body, from a point slightly anterior and external to the pair of large discs from which the depressor muscles originate. It may be remarked in passing that this series of discs is the representative of the *cervical grooves* of the Ixodid ticks. The lower terminations of the levator muscles of the capitulum are inserted into the upper part of the postero-lateral angles of the basis capituli. The action of these two pairs of capitular muscles is sufficiently explained by their respective names.

The *muscles of the chelicerae* are three in number, a *retractor* muscle, and the *flexor* and *extensor* muscles of the *digit.* The *retractor muscles* (*m. r. ch.*) each consist of a stout bundle of fibres which takes its origin from a large aggregation of small discs occupying the middle of the dorsum, immediately posterior to the discs of the depressor capituli muscles. The retractor muscles are inserted into the posterior extremities of the shafts of the chelicerae, along the line where the latter are reflected forwards to form the thin membranous inner cheliceral sheaths. The *flexor* and the *extensor muscles* of the *digit* are contained wholly within the expanded basal portion of the cheliceral shafts (see Part I, pp. 37–38). The *extensor muscle of the digit* is a bipinnate muscle, the strands of which are attached, serially, to the inner surface of the wall of the expanded basal portion of the cheliceral shaft; the latter run forwards and unite to form a central tendon which becomes free of the muscle before passing through the narrow cylindrical portion of the cheliceral shaft, and is finally inserted into the lateral extremity of the expanded base of the digit. The *extensor muscle of the digit*, though smaller than the flexor muscle, resembles it in structure. Its tendon is attached to the mesial side of the base of the digit.

The *muscles of the palp* consist of a pair, a *flexor* and an *extensor*, related to each article. The muscles of the basal article take their origin from the lateral wall of the basis capituli (see Text-fig. 4). The *adductor* (or *extensor*) *muscle* runs forwards and inwards, and is inserted into the inner part of the proximal margin of the first or basal article. The *abductor* (or *flexor*) muscle, which takes its origin from a position on the lateral wall of the basis capituli slightly anterior to the adductor muscle, runs almost directly forwards, and is attached to the lateral part of the proximal margin of the basal article. The contraction of the abductor muscle deflects the entire palp in a lateral direction, while the adductor muscle by its action in the opposite direction restores the palp to its normal position. The remaining muscles of the palps are arranged in pairs, each composed of a *flexor* and an *extensor*, one of which is related to each article of the appendage. These muscles are attached at their bases to the wall of the article immediately proximal to that in which they find their insertion, the terminal article thus receiving only the insertion of the muscles which are contained within the third article.

Like the palps, the musculature of the legs consists of a pair of muscles, of opposing action, related to each article. The only muscles originating from the dorsal integument are those, the lower extremities of which are inserted into the coxae. Of these, the *adductors of the coxae* (*m. add. cx.* 1–4) form an inner series of four stout muscles, one of which is attached to the mesial surface of the proximal margin of the article. The *abductors of the coxae* (*m. abd. cx.* 1–4) form an outer series, and are inserted in a corresponding position on the lateral part of the coxae. These coxal muscles, four pairs on each side of the body, take their origin from a series of moderately large discs which occupy the lateral fields of the anterior half of the body, lying between the closely crowded small marginal discs and the large discs which it has already been shown are associated with the capitular muscles. The integumental discs from which the coxal muscles originate, correspond to the three pairs of short grooves which are generally present on the antero-lateral parts of the dorsal surface of the body of female *Ixodidae*, while in the males of ornate species, the place of these grooves is taken by the *lateral spots*. For fuller information on this point the reader is referred to the work of Dönitz[1]. The coxae contain within themselves a pair of muscles, the *flexors* and *extensors* of the succeeding article of the leg—the *trochanter* (*m. f. tch.* 1–4 and *m. e. tch.* 1–4)—and similarly, each successive article of the leg contains the flexor and extensor muscle which operates on the next succeeding article; the last pair of muscles, situated in the tarsal article, terminates in a pair of long tendons which pass through the caruncle to find their insertions in the pulvillium.

(*c*) The Muscles of the Alimentary Canal.

Under this category are included—(*a*) the *pharyngeal muscles*, (*b*) the *muscles of the oesophagus* and the wall of the *stomach* with its coecal appendages, and (*c*) the *anal muscles*—all of which have been more or less completely dealt with in Part II of this paper in connection with the general anatomy of the alimentary canal (pp. 222–241).

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[1] Dönitz, W. (1909).

As has been shown, the *pharyngeal muscles* form two series—the *dilator muscles* (*m. d. ph.*; *see also* Part II, Text-figs. 2 and 3) and the *constrictor muscles.* The *dilator* muscles of the pharynx consist of six longitudinal series of stout bands which radiate from their points of insertion on the external surface of the pharyngeal wall to their basal attachments; *viz.* the ventral surface of the subcheliceral plate in the case of the dorsal series, and the lateral walls of the basis capituli in the

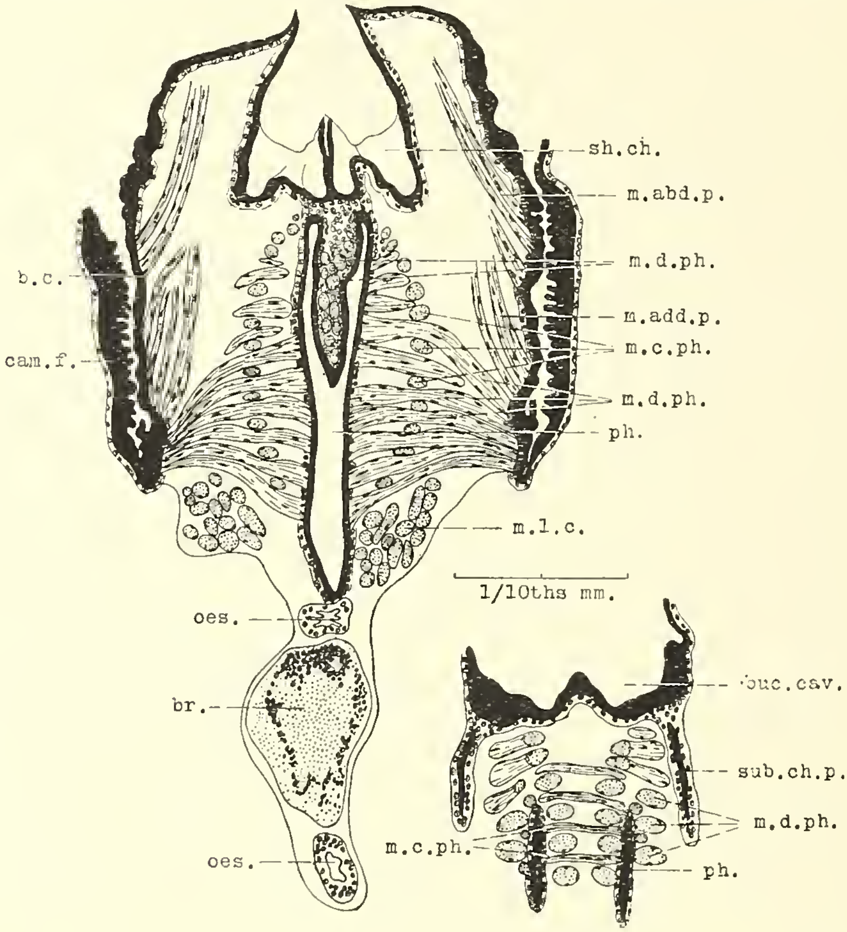

Fig. 4. *Argas persicus* ♀. Horizontal section through the basis capituli, showing the origins and insertions of the lateral dilator muscles of the pharynx, and the muscles of the basal article of the palp. The smaller figure is taken from a section which passes through the antero-dorsal portion of the pharyngeal wall, and shows some of the dorsal dilator and constrictor muscles of the pharynx.

b. c. basis capituli; *br.* brain; *buc. cav.* buccal cavity; *cam. f.* camerostomal fold; *m. abd. p.* abductor muscle of palp; *m. add. p.* adductor muscle of palp; *m. c. ph.* constrictor muscles of pharynx; *m. d. ph.* dilator muscles of pharynx; *m. l. c.* levator muscles of capitulum; *oes.* oesophagus; *ph.* pharynx; *sh. ch.* sheath of chelicera; *sub. ch. p.* sub-cheliceral plate.

case of the lateral series (see Text-fig. 4). The *constrictor muscles* of the pharynx, which are disposed alternately with the individual elements of the series of dilator muscles, form a succession of slender bands connecting the angles formed by the six longitudinal folds of the pharyngeal wall, each complete member of the series thus presenting, in transverse sections through the pharynx, the appearance of a triangular figure with truncated angles.

The muscles of the oesophagus and stomach are represented by the layer of muscle fibres which enters into the formation of the walls of these organs, and sufficient reference has been made to their structure and arrangement in the general description of these organs.

The *anal muscles,* as previously shown (Part II, p. 241), are short strands which connect the upper extremity of the anal canal with the lateral margins of the anal valves.

(*d*) The Muscles of the Genitalia.

The muscles of the genitalia are divided into two groups—(*a*) those which connect some part of the genital tract with the body wall or endosternite, and (*b*) the muscles which form the muscular layers in the walls of the genital canals.

The extrinsic muscles are the *superior* and the *inferior genital muscles* (see Part II, Plate XVI, figs. 3 and 4, *m. gen.*) which are attached to the terminal section of the genital canal but show a slight difference in their relations in the two sexes.

In the male, the *superior genital muscles* take their origin from the ventral surface of the endosternite as a cluster of slender strands which pass almost vertically downwards and are inserted into the proximal part of the dorsal wall of the *ductus ejaculatorius.* In the female, they originate in a similar manner, and find their insertion in a corresponding situation on the dorsal wall of the terminal section of the vagina.

The *inferior genital muscles* arise from the ventral body wall in the post-genital area, and pass obliquely forwards to be inserted into the ventral wall of the *ductus ejaculatorius* in the male, and into the posterior lip of the genital orifice in the female. Further reference is made to these muscles in the description of the genital organs.

In a preceding section of this paper dealing with the body-muscles, brief reference was made to a pair of muscles which are closely connected with the genital organs. These are the *dorso-genital muscles* (*m. gen'.*) which take their origin from a pair of discs situated on the middle of the dorsal surface of the body, some distance posterior to the origins of the retractor muscles of the chelicerae. From the dorsal integument, they run downwards and forwards as a pair of stout muscular columns which, after passing beneath the posterior margin of the last pair of mesial intercoxal muscles, are inserted along the grooves which define the lateral margins of the post-genital area. From their relations with the terminal portion of the genital canal, it would appear that their function is principally concerned in the operation of oviposition in the female and the extrusion of the spermatophores in the male.

The muscles of the walls of the genital tract reach a high state of development in the female, but their detailed description will be more conveniently dealt with in connection with the genitalia.

THE NERVOUS SYSTEM.

See Part II, Plates XIV–XVI.

The nervous system of *Argas persicus* conforms essentially to the *Acarine* type, in the fact that the entire *central* portion is fused into a single large ganglionic mass which surrounds the oesophagus, and from which the whole system of peripheral nerves takes its origin.

As far as it was possible to study the structure of such small structures by fine dissection alone, the nervous system of this species was worked out by Heller[1], and, though his description is somewhat brief, present knowledge has but little to add in amplification or modification of his observations. Pagenstecher described the nervous system in two species of ticks—*Ixodes ricinus* in the one case[2], and *Argas reflexus* in the other[3],—but, beyond the fact that he established the number and arrangement of the nerve roots which arise from the central nerve mass with more accuracy and precision than Heller, his investigations do little more than confirm previous knowledge.

Concerning the finer anatomy of the central nervous system in ticks, the earliest work with which we are acquainted is that of Wagner[4], who, in his researches on the embryology of *Ixodes calcaratus* Bir., made some interesting observations which will be referred to later. For the most recent and detailed account of the histological structure we are indebted to Nordenskiöld, who, in his investigations on the anatomy and histology of *Ixodes ricinus,* describes three distinct types of nerve cells which he found to be distributed in the ganglionic layer of the central nerve mass[1]. A short but useful general account of the nervous system is to be found in Bonnet's work on the comparative anatomy and development of ticks[2].

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[1] Heller, O. (1858), p. 311.

[2] Pagenstecher, H. A. (1861).

[3] Pagenstecher, H. A. (1861 *c*).

[4] Wagner, J. (1894).

The Central Nervous System.

The *central nerve mass* or "brain" of *Argas persicus* is situated in the anterior part of the body, immediately below the anterior margin of the stomach, *i.e.* the place where the latter organ bifurcates to form the antero-lateral coecal lobes. Its ventral surface rests upon the dorsal surface of the terminal portion of the genital tract—the *vagina* in the female, the *ductus ejaculatorius* in the male. The organ is traversed longitudinally by the oesophagus, which enters in front, some little distance below the anterior margin, and passing obliquely upwards

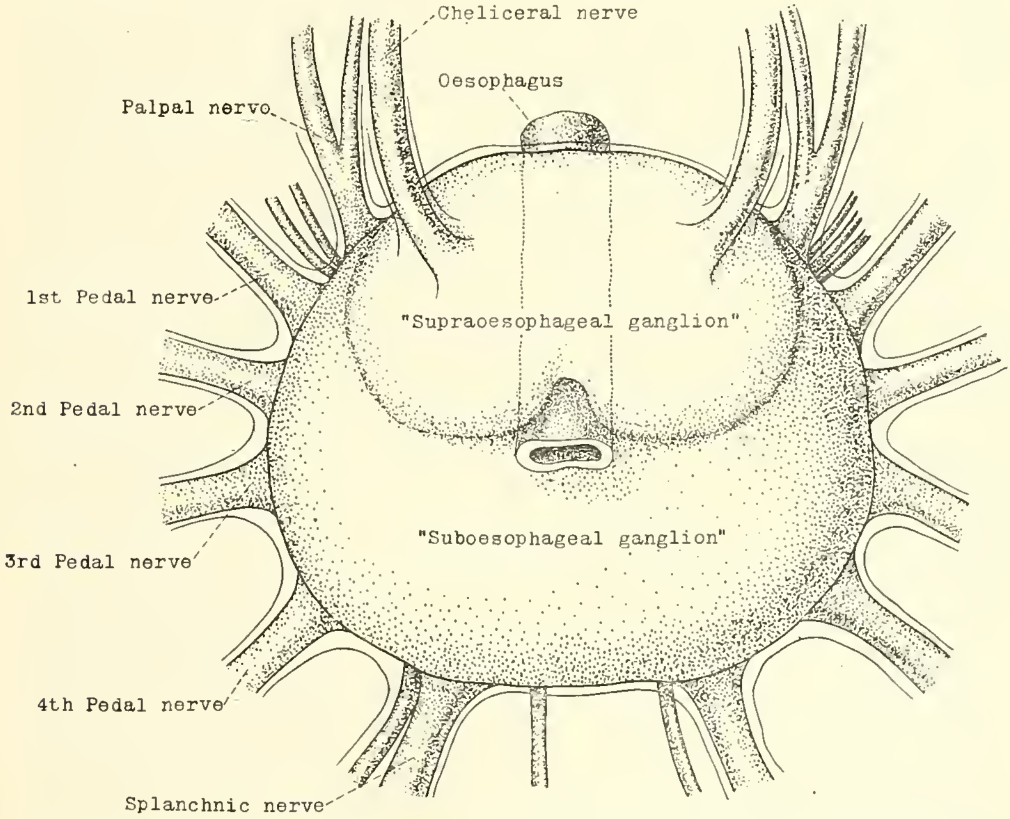

Fig. 5. *Argas persicus* ♀. The central nervous system from the dorsal aspect. The outermost line, which follows the contour of the "brain" and is continued along the nerve roots, represents the periganglionic sinus. Slightly schematised.

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[1] Nordenskiöld, E. (1909 *c*), pp. 461–464.

[2] Bonnet, A. (1907), pp. 26–34.

through the organ, emerges on the centre of the dorsal surface, after leaving which, it almost immediately joins the stomach.

As seen under a low magnification, the brain presents the appearance of a rounded, compact, creamy-white organ, measuring about 0·4 mm. in length; the maximum breadth usually exceeds the length, but becomes perceptibly narrower in the anterior portion. The dorsal surface is rounded, that portion lying anterior to the oesophagus being especially prominent; the ventral surface is broad and flattened, and the lateral margins are slightly indented between the roots of the four large trunks of the pedal nerves (see Text-fig. 5).

It has already been shown that the brain is completely surrounded by the periganglionic blood sinus (see Part II, p. 243) and thus receives its blood supply direct from the heart.

In sections of the brain, the organ is seen to be completely invested in a closely adherent, connective tissue sheath or *neurilemma*, which is reflected at the point of entry of the oesophagus to form a continuous sheath, which surrounds and separates the latter from the actual brain substance. The nervous tissue of the brain consists of a peripheral zone of ganglion cells surrounding a central mass of molecular substance, which is traversed in all directions by the nerve fibres which form the various commissures and connectives which link up the different ganglia. The superficial layer of ganglion cells is not of uniform thickness throughout its extent, being so thinned out in places as to almost completely disappear, while in other places the ganglion cells extend as wedge-shaped masses down into the molecular central portion, and thus define the ganglia from which the main nerve trunks originate.

In spite of the extreme degree of fusion of the individual ganglia of which the central nerve mass is composed, it is by no means difficult to recognise these ganglia in sections of the brain. At first sight the brain appears to consist of a "supraoesophageal" and a "suboesophageal ganglion," which are united on either side of the oesophagus by a stout connective. A single pair of nerves arises from the "supraoesophageal ganglion," the remainder all taking their origin from the "suboesophageal ganglion." From a study of vertical and horizontal sections of the brain, it is seen that these "ganglia" are divided into a number of true ganglia from which the main nerve trunks take their origin, and the relations of these constituent ganglia are readily established (see Text-fig. 6).

The supraoesophageal portion of the brain is then seen to consist of two pairs of ganglia, the smaller pair of which is situated in the above-

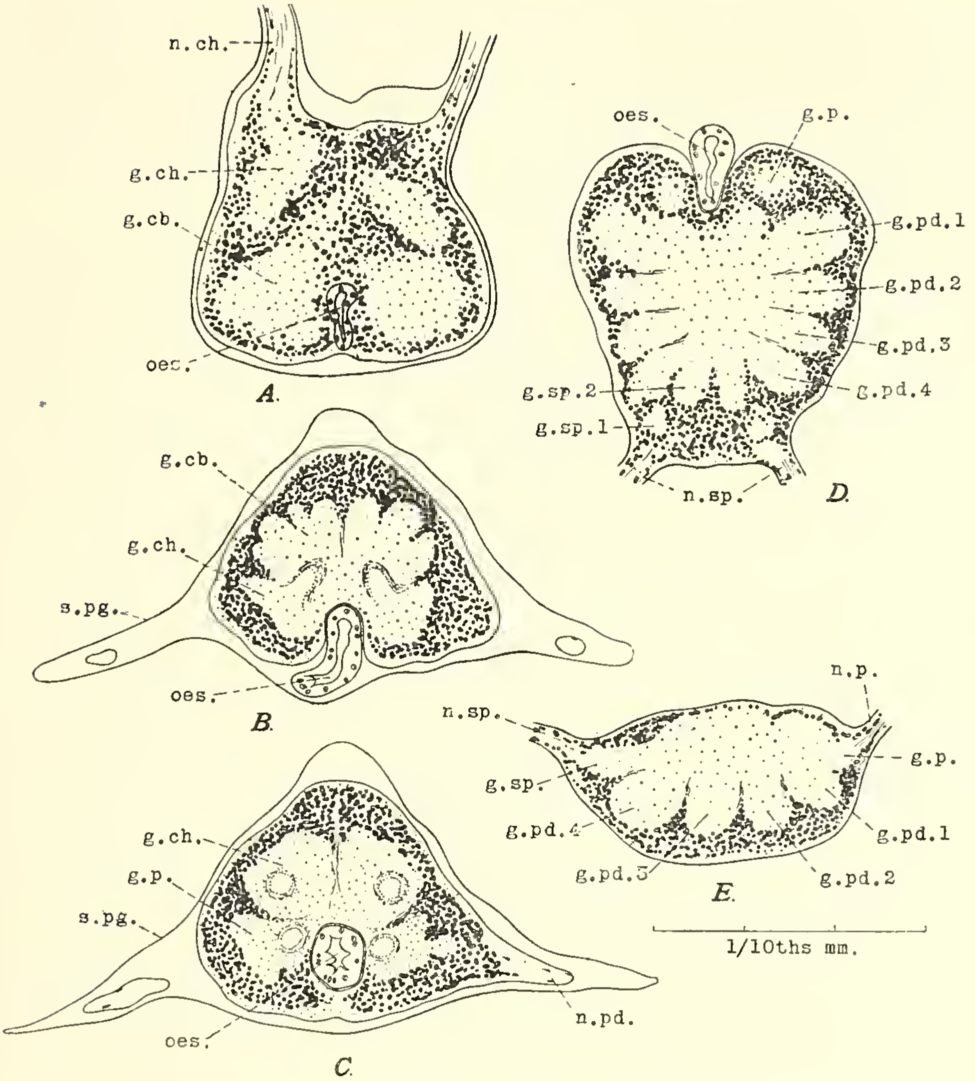

Fig. 6. *Argas persicus* ♂. Sections through the central nervous system, showing the disposition of the component ganglia. *A*. Horizontal section through the *supra-oesophageal* portion, showing the *cerebral* and *cheliceral* ganglia; *B*. Transverse section through the same part; *C*. Transverse section some little distance posterior to *B*, showing the *cheliceral* and *palpal* ganglia; *D*. Horizontal section through the *suboesophageal* portion, showing the *palpal*, *pedal* and *splanchnic* ganglia; *E*. Vertical longitudinal section of lateral portion of "brain," showing the *palpal*, *pedal*, and one of the *splanchnic* ganglia.

The peripheral distribution of the ganglion cells is clearly indicated in the sections, the centrally-situated fibro-molecular substance being represented by stippled shading.

g.cb. cerebral ganglion; *g.ch.* cheliceral ganglion; *g.p.* palpal ganglion; *g.pd.* 1–4, pedal ganglia; *g.sp.* 1–2, splanchnic ganglia; *n.ch.* cheliceral nerve; *n.p.* palpal nerve; *n.pd.* pedal nerve; *n.sp.* splanchnic nerve; *oes.* oesophagus; *s.pg.* periganglionic sinus.

mentioned dorsal prominences lying immediately anterior to the efferent portion of the oesophagus. These are the true *cerebral ganglia*, which in the Ixodid ticks give rise to the optic nerves, and the nerves of the porose areas, in those cases where such organs are present; in *Argas*, however, these sensory organs are absent, and apparently no nerves are derived from the cerebral ganglia.

The *cheliceral ganglia*, which form the anterior portion of the "supraoesophageal ganglion," are situated immediately below and in front of the cerebral ganglia, and from the antero-dorsal face of each the *cheliceral nerve* issues. A stout bundle of nerve fibres forms a connective, which descends from each of the cheliceral ganglia, the two connectives passing down on either side of the oesophagus and forming a connection between the cheliceral ganglia and the suboesophageal portion of the brain[1].

The suboesophageal portion forms the greater part of the brain, and, as already stated, all the remaining nerves originate from this part. The first pair of ganglia—the *palpal ganglia*—are situated in the antero-lateral region, on either side of the place of entry of the oesophagus, and give rise to the nerves which innervate the palp. The entire lateral region of the suboesophageal portion of the brain is divided into four successive ganglia, the *pedal ganglia*, from each of which a pedal nerve takes its origin. The posterior part of the brain, lying behind and between the fourth pair of pedal ganglia, is seen to consist of four small *splanchnic ganglia*, disposed in pairs on either side of the median line, from which the splanchnic nerves derive their origin.

The nerve cells which constitute the peripheral ganglionic layer of the brain are all of the unipolar variety (see Text-fig. 7). We have succeeded in identifying, in *Argas persicus*, two of the three different types which Nordenskiöld found to exist in the brain of *Ixodes ricinus*[2]. The larger ganglion cells are, for the most part, confined to the dorsal portion of the brain, immediately posterior to the place of exit of the oesophagus. A few large cells are, however, scattered among the ganglion cells in the ventral portion of the brain. All the remaining nerve cells are of practically uniform size and agree in their appearance with the "medium-sized" cells which Nordenskiöld has described. The small ganglion cells do not appear to be represented in this species.

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[1] The origin of the *cheliceral nerves* from the supraoesophageal portion of the brain is apparently secondary. Wagner observed that in the developing larva of *Ixodes calcaratus* Bir. the *cheliceral ganglia* appear as the first of the series of six pairs of *thoracic ganglia*, and are then situated below the oesophagus, but in the subsequent process of condensation, they ascend to the supraoesophageal position and fuse with the *cerebral ganglia*. It may be remarked that the *palpal ganglia* are also involved in a lesser degree, as is indicated by the position on either side of the oesophagus which they ultimately attain.

[2] Nordenskiöld, E. (1909 *c*), p. 462.

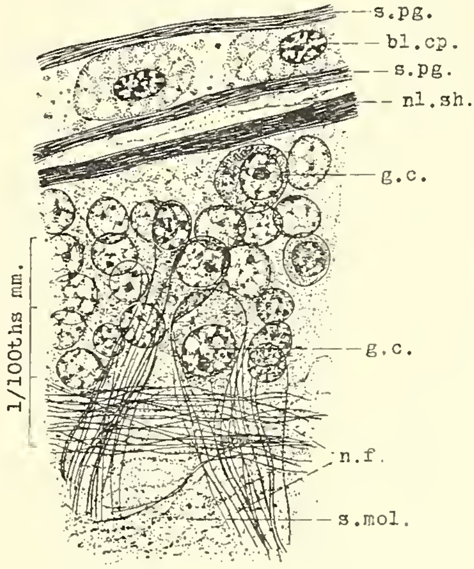

Fig. 7. *Argas persicus* ♂. Transverse section of a portion of the ganglionic layer, from the ventral part of one of the pedal ganglia.

bl. cp. blood corpuscle; *g. c.* ganglion cells; *n. f.* nerve fibres; *nl. sh.* neurilemma sheath; *s. mol.* molecular substance; *s. pg.* periganglionic sinus.

The Peripheral Nervous System.

Seven pairs of large nerve trunks arise directly from the central nervous system in *Argas persicus*, viz.

1. The cheliceral nerves.
2. The palpal nerves.
3. The nerves of the 1st pair of legs.
4. „ „ „ 2nd „ „
5. „ „ „ 3rd „ „
6. „ „ „ 4th „ „
7. The splanchnic nerves.

In addition to these, however, a variable number of small nerves arises directly from the brain, one group originating close to the bases of the palpal nerves, while the remainder are irregularly distributed along the posterior margin and are apparently associated with the splanchnic trunks (see Text-fig. 5). It is the presence of these smaller nerves, and the fact that the main trunks themselves may occasionally divide into two branches immediately at their point of issue from the brain, that has given rise to the discrepancies in the literature. Heller, for instance, alludes to the presence of 18–19 nerve trunks radiating directly from the brain in *Argas persicus*[1], and in *Ixodes ricinus*, 11 pairs of nerves were described by Pagenstecher[2]. Heller also found a median unpaired nerve which took its origin from the anterior part of the brain and ran forwards beneath the oesophagus to the mouth-parts, but, so far as we know, nobody has since succeeded in confirming this observation.

The structure of the nerves is apparently simple. Each trunk is closely invested by a thin *neurilemma* sheath which is continuous with that of the brain. Immediately below the *neurilemma,* large elliptical nuclei are distributed at intervals, which rest on the external surface of a central core of fine longitudinally-disposed nerve fibrils, the latter forming the greater part of the mass of the nerve. It has been previously shown that each of the main nerve trunks runs, freely suspended, within the lumen of an arterial branch of the periganglionic blood sinus (see Part II, pp. 243–244).

The *cheliceral nerves* arise from the antero-dorsal extremity of the supraoesophageal portion of the brain, and immediately beyond the point of origin each nerve runs directly upwards to the proximal extremity of the shaft of the corresponding chelicera, where it divides into two branches, one of which enters the base of the shaft and innervates the *digital muscles,* while the posterior branch ramifies among the *retractor muscles.*

The *palpal nerves* take their origin from the antero-lateral angles of the brain, on either side of the oesophagus. They run forwards alongside the pharynx, near the posterior end of which each gives off a mesial branch which runs towards the middle line of the body and loses itself among the pharyngeal muscles, while the main branch continues to the base of the palp which it enters.

The four pairs of *pedal nerves* spring from the lateral margins of the brain, each trunk passing outwards to its respective appendage. Each pedal nerve divides into two equal branches at a point about mid-way between the brain and the coxa.

The *splanchnic nerves* originate from the postero-lateral angles of the brain, from which they pass almost directly backwards, their branches innervating the alimentary canal, the genitalia and the body-muscles.

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[1] Heller, C. (1858), p. 311.

[2] Pagenstecher, H. A. (1861), p. 36.

The Sensory Organs.

Although *Argas persicus* quickly responds to such external stimuli as *light* and *heat*, the only recognisable sensory organs which it appears to possess are the *tactile hairs*, which are present on various parts of the body and appendages, and *Haller's organ*, the function of which has been finally and definitely settled by the recent experimental investigations of Hindle and Merriman[1].

The *tactile hairs* are identical in their general form with the corresponding structures in the Ixodid ticks, and call for no special comment. The most important, conspicuous by reason of their relatively large size and concentration, are those with which the extremity of the terminal article of the palp is furnished. Long tactile hairs are also found, sparsely scattered on the legs, more especially on the tarsal articles. Hindle and Merriman have called special attention to the well-marked tendency to bring as much of its body surface into contact with surrounding objects as possible, which this tick shows in all stages of its development[2]. Whether this "positive thigmotropism" is the manifestation of a special instinct, or whether it is only a secondary result of the tick's inherent desire for concealment and avoidance of light, appears to be open to question. It is, however, certain that the entire surface of the tick's body is extremely sensitive to the stimulus of contact.

Haller's organ, in its structure and situation, is identical with the corresponding sensory organ in other ticks. The only material difference in the structure of the organ, from that of such a form as *Haemaphysalis punctata*, is that the vesicle containing the sensory hairs is relatively deeper, and the pore which communicates with the exterior is larger; and also, the *sensory hairs* are apparently confined to the lower portion of the vesicle, while the crowded hairs with which the vesicle is filled apparently serve a protective function only.

As already pointed out, although no eyes are present, *Argas persicus* displays a marked dislike to exposure to light, and it would appear, in the absence of any recognisable photo-sensitive organ, that the light sense is distributed over the entire body surface. The investigations of Hindle and Merriman support this view, and they make special allusion to the fact that in the larval and early nymphal stages, when the cuticle is very thin, the response to the stimulus of light is more active than in the mature stages when the cuticle is thicker and less transparent[1].

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[1] Hindle, E. and Merriman, G. (1912).

[2] Hindle, E. and Merriman, G. (1912), p. 208.

For detailed information on the sensory perceptions of this tick, the reader is referred to the excellent paper cited above.

THE GENITAL ORGANS.

Plates XXVI–XXVIII (see also Part II, Plates XIV–XVI).

The genital organs of *Argas persicus*, as is the case in the ticks as a whole, are situated in the middle part of the body, between the alimentary canal and the ventral body wall. The gonad—*ovary* or *testis* as the case may be—is an unpaired organ which lies transversely across the posterior half of the body, just in front of the anterior limit of the posterior-median dorso-ventral body-muscles; from each lateral extremity an efferent canal—*oviduct* or *vas deferens*—takes its origin and after a somewhat tortuous course this canal opens, together with its partner of the opposite side, into a common median receptacle, the *uterus* in the female and the *seminal vesicle* in the male. From the median receptacle, a short canal leads directly forwards to the external genital orifice. In both sexes, certain *accessory glands* are associated with the terminal unpaired section of the genital tract, these glands in the case of the male assuming an extraordinary degree of complexity.

From the foregoing general account, it is seen that the genitalia of this tick agree, in the essentials of their form and arrangement, with the sexual organs of other ticks, and indeed, so far as present knowledge extends, with those of the *Acarina* generally.

No separate *receptaculum seminis* is developed in the female, as we know to be the case in some, if not all, of the *Ixodidae*.

In common with all the *Ixodoidea*, *Argas persicus* is oviparous and the spermatozoa are extruded in the form of spermatophores. No special intromittent organ is developed in the male, the spermatophore being introduced into the female genital canal by the capitulum of the male.

The genital organs apparently attain their complete development, so far as the various parts are concerned, in the *deuteronymph*, though, of course, the sexual glands are then immature and the opening to the exterior is not patent.

The subsequent changes are by no means easy to follow, and in the following pages we shall confine ourselves principally to a description of the anatomy of the genital organs as they appear in the mature adult, shortly after engorgement. In the female, particularly, different parts of the genital system are, more or less, always in a state of change, and though the gross anatomy is not much affected thereby, the study of the histological structure of the ovary, the walls of the uterus and the oviduct, is rendered exceedingly difficult by the fact that degenerative and regenerative phases may be exhibited simultaneously in various regions of the genital tract.

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[1] Hindle, E. and Merriman, G. (1912), p. 206.

The observations which were made in connection with the anatomy of the alimentary canal (Part II, p. 235) apply here with even greater force, and it would necessitate the collection of a large supply of carefully prepared material, the history of which was definitely known, in order to work out these phases of development in a satisfactory manner, a fact that we did not sufficiently realise when preparing the material, the study of which has furnished the matter for this paper.

The Female Genital Organs.

The female genital organs are comprised of:

1. The Ovary.
2. The Oviducts.
3. The Uterus.
4. The Vagina.
5. Gené's organ.

The Ovary.

Plate XXVI, figs. 1–5 (see also Part II, Plate XIV *ov.*).

The *ovary* (*ov.*) is situated in the posterior half of the body, its median portion lying between the rectum in front and the foremost columns of the postero-median dorso-ventral muscles behind ; it is covered dorsally by the postero-lateral coecal lobes of the stomach and its ventral surface rests upon the anterior portion of the rectal sac.

The organ consists of a broad strap-like tube with thick walls, which lies transversely across the body, its entire length measuring approximately one-half of the body width. The ovary frequently appears to be twisted and crumpled by the pressure of the superposed alimentary coeca. The external surface is densely studded with small spherical bodies—the immature ova.

In transverse sections of the ovary, its wall is seen to be formed of a thick epithelium composed of cells of variable size and appearance which rest upon a thin structureless basal membrane. From this ovarian epithelium the ova (*o. o'.*) are derived and in a young female they may be recognised in all stages of development, scattered among the smaller unaltered cells which are always present in large numbers.

As the ova increase in size, they approach the basal membrane of the ovarian epithelium and, simultaneously, a proliferation of the adjacent unaltered epithelial cells takes place with the result that a pedicel (*p. ov.*) is formed, upon the extremity of which the rapidly growing ovum is pushed out of the epithelium, carrying the basal membrane before it, as a closely investing ovarian follicle (*f. ov.*). In this manner the ovum finally comes to rest on the external surface of the ovarian epithelium, with which it remains connected by the narrow neck-like pedicel, and still enveloped by the thin membrane or follicle derived from the basal membrane.

While still forming a part of the actual ovarian epithelium, the developing ova begin to show aggregations of yolk granules in their cytoplasm and it is to this accumulation of yolk granules, rather than the enlargement of the nucleus, that the rapid increase in size is due. The nuclei of such young ova are more or less spherical in form and rich in chromatin and surrounded by a pale and finely granular cytoplasm. (See Plate XXVI, fig. 4.) The extra-ovarian ova often assume a more or less pear-shaped form, the smaller end being the point of attachment to the pedicel. The whole of the cytoplasm is densely crowded with yolk granules, and the nucleus, which attains a considerable size, generally presents an oval or elliptical form, is relatively poor in chromatin, and contains a large deeply-staining nucleolus (see Plate XXVI, figs. 2, 3).

Up to this stage, the ovum is devoid of a shell and the idea that the shell is the product of the thin membranous ovarian follicle is quite untenable[1]. A portion of the wall of the ovarian tube is formed of cells which present a gland-like appearance (Plate XXVI, fig. 2, *gl. ov.*) and it is possible that this ovarian gland secretes the shell of the ovum. On the other hand, we have never seen spermatozoa at a higher point in the female genital tract than the upper part of the oviduct, and even then they have been isolated examples, the great majority of the spermatozoa remaining in the uterus and the lower part of the oviduct. Owing to the apparent impossibility of a spermatozoan penetrating the stout chitinous shell of the mature ovum, and, so far as we know there is no micropyle, fertilisation of the ova must be accomplished prior to the formation of a shell, in which case the shell is probably secreted by the epithelial lining of the oviduct. All who have written on the subject of the genitalia of the ticks are curiously reticent on this point, and it appears to us to be by no means unimportant, in view of the fact that pathogenic protozoa—*e.g. Piroplasma bigeminum*—are transmitted from the female tick, *via* the egg, to the larva, which is thus infective from the time of hatching.

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[1] See Heller, C. (1858), p. 315.

The Oviducts.

The *oviducts* (*d. ov.*) consist of a pair of relatively thick-walled tubes which take their origin from the lateral extremities of the ovary, from which they run forwards, following a convoluted course, as far as the anterior extremity of the uterus; at this point they suddenly turn inwards and backwards and run along the lateral margins of the uterus, which they enter at its respective posterior angles. From the point where the course of the oviducts is reflected to their union with the uterus, their diameter is considerably enlarged.

The wall of the oviduct is formed of three layers,—an inner epithelial layer of very elongated columnar cells, with small pale nuclei situated near their bases—a middle layer of muscular fibres, disposed in a circular direction, but upon the external surface of which a number of separated longitudinal muscle bands are disposed—and an outer layer of flattened epithelial cells. The free margin of the columnar cells of the lining epithelium usually presents a frayed and ragged appearance, and the cells encroach so far into the interior of the tube as to almost occlude its lumen. The upper and thinner portion of the oviduct differs somewhat from the lower portion, in the fact that the muscular layer is not so strongly developed, while the epithelial lining is almost suppressed on one side of the duct, and as the remaining epithelial cells extend across the duct for some distance beyond its centre, the lumen is excentric.

The lower and thicker portion of the oviduct ultimately becomes distended with spermatozoa and the histological details of its walls are to a great extent destroyed.

The Uterus.

The *uterus* (*ut.*) is a large median unpaired sac of triangular form which is situated in the middle of the body, between the stomach and the ventral body wall. The posterior angles are somewhat drawn out in the form of cornuate extensions, into the extremities of which the oviducts open.

The structure of the wall of the uterus resembles that of the lower part of the oviduct, in fact the latter almost appears to be a continuation of the former; but, as the sac becomes enormously distended with spermatophores, the walls of the body of the uterus are so thinned out, that the original character of the epithelial lining is completely destroyed. The narrower portion, or neck, of the uterus, being less subject to dilation, generally exhibits the normal structure, particularly in the portion near the place of transition from the uterine to the vaginal epithelium (see Plate XXVI, fig. 7, *ut.*). The epithelial lining consists of closely-packed elongate columnar cells, with elongated nuclei situated at the basal portion of the cells. The muscular layer consists, for the most part, of circular and oblique fibres, but the longitudinal fibres which form the outer portion of the muscular sheath are not collected into separated bands, and are more numerous than those of the oviduct.

The uterus functions as a *receptaculum seminis,* and though the usual number is one or two, we have observed as many as eight unruptured spermatophores in the sac at one time; and as the latter each measure about 0·8 mm. in length by 0·6 mm. in breadth, the extreme degree of distension, to which the sac is subject, is no matter for surprise.

Sooner or later, the thin membranous envelopes of the spermatophores rupture, and the contained spermatozoa are found free within the uterus and the lower dilated portion of the oviduct.

The Vagina.

The *vagina* (*vg.*, *vg′.*) comprises that portion of the common genital canal which extends from the uterus to the external genital opening, and is distinguished from the rest of the genital tract by the fact that it is lined throughout with a thin internal sheath of chitin which is continuous at the external genital opening with the general cuticle of the body.

In ordinary dissections, it is possible, from the external form alone, to distinguish two distinct portions of the canal, while sections through the part show structural differences of a very marked character.

The proximal or *cervical portion of the vagina* (Plate XXVI, figs. 6, 7, *vg′.*) is a short, stout, cylindrical or barrel-shaped tube, one end of which is partially telescoped into the neck of the uterus, generally a little towards the ventral side of the latter, while the other end turns upwards and opens into the under surface of the broad flattened canal which forms the distal or *vestibular portion of the vagina* (*vg.*). The two sections of the vagina overlap one another to a slight extent, the posterior end of the vestibular portion forming a very shallow blind pouch or *cul-de-sac* into which a pair of *accessory glands* (*gl. ac. gen.*) opens.

At the uterine extremity of the vagina, its epithelium is partially prolapsed into the cavity of the uterus in the form of a rosette with a depressed central portion, which marks the site of the opening of the narrow lumen of this portion of the vagina. The epithelium of the cervical portion is composed of columnar cells, the arrangement of which is complicated by the fact that the epithelium is thrown into a series of deep longitudinal folds, with the result that in longitudinal sections (see Plate XXVI, fig. 7), the nuclei of the cells appear to be scattered indiscriminately through the entire thickness of the epithelium. The thin chitinous intima everywhere maintains its connection with the free margins of the epithelial cells, dipping down in the deep narrow clefts which divide the longitudinal folds. The epithelial layer is surrounded by a thick sheath formed of several layers of circularly-disposed muscle fibres (*m. vg.*). This muscular sheath is continuous behind with the muscular layer of the wall of the uterus (*m. ut.*), but at the anterior extremity of the cervical portion of the vagina, it comes to an abrupt termination. From the dorsal surface of the muscular sheath, several small bundles of muscle fibres arise, some of which pass, upwards and forwards, directly to their places of attachment to the proximal end of the vestibular portion of the vagina, while others, arising from the lateral portions of the dorsal surface of the muscular sheath, pass upwards and obliquely forwards, and crossing each other on the way are inserted into the opposite sides of the proximal end of the vestibular portion of the vagina.

In addition to the above-mentioned muscles, a number of fibrils, which appear to be muscular in nature, are present in the epithelial layer. They arise from the inner surface of the circular muscular sheath and pass directly towards the lumen of the vagina, their extremities being lost among the epithelial cells, or in some cases they apparently reach, and become attached to, the inner surface of the chitinous intima.

The *vestibular portion of the vagina* (*vg.*) consists of a broad flattened tube which leads directly to the external genital opening. Its chitinous lining is considerably thicker than that of the preceding portion, and its exposed surface is completely covered with minute pointed scale-like papillae which are disposed in transverse rows. Beneath the chitinous lining is a layer of small columnar epithelial cells which is thrown into regular transverse folds, but, unlike that of the preceding section of the vagina, the chitinous lining does not dip between these folds, but passes directly over them.

As already mentioned, the *accessory glands* (*gl. ac. gen.*) open into the shallow *cul-de-sac* formed by the posterior end of the vestibular portion of the vagina, immediately above and behind the opening in the floor of the latter, through which communication is established between the two sections of the vagina. They consist of a pair of sausage-shaped glands which are attached externally to the dorsal surface of the vestibular portion of the vagina, immediately anterior to the groove which separates the latter from the cervical portion. Each gland, which is of the simple tubular type, extends backwards for a short distance over the dorsal surface of the uterus (see Plate XXVI, fig. 6, *gl. ac. gen.*). The size of the accessory glands is variable, but the maximum development is attained at the time of oviposition, a fact which suggests that their function is concerned in this process. The gland is composed of large columnar cells with rounded nuclei and a deeply-staining, coarsely granular cytoplasm. The lumen of the gland is very small.

The complexity of the structure of the vagina in *Argas persicus* finds an explanation, without doubt, in the fact that in addition to its ordinary function as a mere channel for the passage of the ova and spermatophores, it plays an important part in the process of oviposition. Unfortunately, we have never had an opportunity of observing this process in *Argas*, but there is no reason for supposing that it differs from the act of oviposition in the Ixodid ticks; and from what we know of the latter, we attempt to explain the function of the two parts of the vagina as follows:

The vestibular portion of the vagina during the act of oviposition becomes completely evaginated and prolapses through the external genital opening in the form of a short ovipositor with a truncated extremity. By the contractions of the uterine walls, and also of the dorso-ventral body-muscles, the ova are forced, one by one, into the contracted anterior portion, or neck, of the uterus, which is only sufficiently large to accommodate a single ovum. The cervical portion of the vagina then comes into action. The everted lips of the latter, which, as shown above, protrude into the cavity of the uterus, insinuate themselves over the ovum, which is maintained in position by the contraction of the uterine muscles, and gradually the ovum is manipulated by the action of the complex arrangement of muscles surrounding the cervical portion of the vagina, first into this portion of the vagina and then to the base of the ovipositor, the final extrusion being brought about by the contraction of the dorso-ventral body-muscles, particularly the dorso-genital muscles. A copious secretion of fluid by the accessory glands serves to lubricate the terminal portion of the vaginal canal, and thus to facilitate the passage of the eggs.

The eggs of *Argas persicus* are almost spherical in form, and have a diameter of 0·6–0·8 mm. The shell is dark yellowish-brown in colour and its external surface is ornamented by a very delicate reticulation which is generally concealed by the adherent moist secretion of Gené's organ.

Gené's Organ.

Plate XXVI, figs. 8–10, Plate XXVIII; *see also*
Part II, Plate XIV, *Gen. org.*

Gené's organ, so named by Nuttall[1] in honour of its discoverer[2], is solely concerned in the act of oviposition and is, therefore, peculiar to the female tick. It is, we believe, universally present in all the *Ixodoidea*, and has been the subject of more or less detailed consideration in most of the works dealing with tick anatomy in recent times. It has been described under various names—*cephalic gland, subscutal gland, ovipositing gland,* and others; and has, moreover, been the subject of some very strange and erroneous conceptions.

The organ makes its first appearance during the final nymphal moult, but only attains its maximum development by the time that the sexual organs have acquired their full activity. It consists of a pair of eversible membranous sacs, derived from the chitinous cuticle of the body, which in the non-active state are contained within a pair of similar sacs of hypodermal origin, and into which the efferent ducts of a pair of large glands opens. Gené's organ is situated entirely in the anterior part of the body, its median portion lying immediately above the anterior margin of the capitular foramen, while the glandular portion extends laterally and posteriorly for some distance within the body cavity.

It has already been seen (Part I, p. 34; Plate III, fig. 7) that the external opening of Gené's organ is a broad crescentic slit with everted lips, which extends across the camerostomal depression immediately anterior to the fold formed by the union of the camerostomal integument with the proximal margin of the dorsal part of the basis capituli. To the margins of this external opening, the common mouth of the paired membranous and hypodermal sacs is attached all round, the membranous portion being here directly continuous with the external cuticle of the body, while the hypodermal portion joins the general hypodermis in a corresponding manner.

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[1] Nuttall, G. H. F. (VII. 1908), p. 16 repr.

[2] Gené, G. (1844).

The arrangement of these parts may be briefly described as two adjacent invaginations of the body cuticle and hypodermis at the site of the external slit, both invaginations possessing a common opening: they may aptly be compared to two pairs of breeches with very wide and baggy legs, one pair within the other. The legs of the breeches are closed at their nether extremities, while the waist-band is represented by the external opening of the organ.

The outer pair of breeches is represented by the hypodermal sacs, into which the wide efferent ducts of the laterally-placed glands open, one on either side, at the place corresponding to the pocket openings of the breeches.

Into the posterior extremity of each of the hypodermal sacs, a small bundle of muscle fibres is inserted, the proximal end of which takes its origin from the body wall just anterior to the capitular foramen (Plate XXVI, figs. 8–9, *m. r. gen. org.*). These muscles play an important part in effecting the restoration of the organ to its resting condition after the eversion of the membranous sacs.

Plate XXVIII shows two transverse sections through the anterior part of the body of a female *Argas persicus*. The first section is situated at the level of the fold which is formed by the junction of the dorsal face of the capitulum with the integument of the camerostome. This fold (*cam.*) just appears in the central portion of the section, lying between the capitulum below, and Gené's organ above.

The second section is taken at a level some distance posterior to the former, but still anterior to the capitular foramen. In this section, the two halves of Gené's organ appear completely separated, and the outer hypodermal sac (*hd. s.*) with the glandular portion opening into it, is clearly distinguishable. Within this hypodermal sac, a curiously folded and crumpled continuous line represents the section of the inner chitinous sac (*ct. s.*, *ct. s'.*) which presents, in its resting state, a collapsed and flattened appearance. The same parts are represented in the first section, but this section is intended to show the relations of the parts of Gené's organ with the general integument of the body, and is complicated by the continuity of the two sacs with the hypodermis and cuticle of the body wall. In this section, the glandular portion (*gl. Gen. org.*) is cut in a plane slightly anterior to its connection with the hypodermal sac, and appears, therefore, to be completely separated from the latter.

From a study of these sections, the thin walls of the chitinous sacs are seen to be folded in a very curious manner, and it may be observed that many of these folds are absolutely constant in their forms and relations, in different individuals. In the mesial portion, where, it will be noticed, the chitinous membrane is stouter than elsewhere (*ct. s'.*), a number of longitudinal folds appear (see also Plate XXVI, fig. 8), which in transverse section present an **S**-shaped figure. These folds extend from the mouth of the chitinous sac almost to its posterior extremity, and, unlike the thin and flexible membranous chitin which forms the major part of the sac, they are sufficiently stiff and substantial to maintain their form, or at least are able to resume their original form, by virtue of their elasticity, when the everted sac returns to the resting state. A small portion which is thrown into a series of fine longitudinal folds may always be observed lying close to the **S**-shaped folds; these are shown in the lower section (Plate XXVIII) as a series of small regular undulations. What the functions of the stiff folds of the chitinous sac may be, we cannot determine with certainty, but it is suggested that they are concerned in some way with the restoration of the everted chitinous sac to its resting position. A small salient longitudinal fold of the wall of the hypodermal sac extends into the space formed by the curve of the lower limb of the **S**-shaped fold, and, in all probability, assists in maintaining the chitinous sac in a correct position during the resting state. This hypodermal fold appears in the sections as a small tongue-like extension from the inner surface of the hypodermal sac (see Plate XXVI, fig. 9; and Plate XXVIII).

The glandular portion of Gené's organ (*gl. Gen. org.*), as already has been shown, opens into the space between the hypodermal and the chitinous sacs. The gland proper is divided in a digitate manner into a number of simple tubules with thick walls and blind extremities. These tubules extend laterally and posteriorly within the body cavity, and in the active phase of the organ may attain a very considerable size. Each tubule is lined with a thick secretory epithelium composed of large columnar cells (see Plate XXVI, fig. 10), the bases of which rest on a thin homogeneous basal membrane which forms the covering capsule of the tubule. The nuclei of the secretory cells are moderately large and rich in chromatin, and are generally situated near the central portion of the cell. The cytoplasm is pale and shows a coarse reticulum of spongioplasm, the interstices of which are filled with the hyaline fluid secretion. The mouths of the gland tubules open collectively into a broad duct which runs towards the middle line of the body, and, as shown above, communicates directly with the cavity of the hypodermal sac.

Nuttall has described and figured the operation of oviposition in *Haemaphysalis punctata*[1] and there is every reason for believing that the operation is very similar if not quite identical in *Argas persicus*.

The chitinous sacs are presumably everted by the rapid secretion of fluid by the glands of Gené's organ, which fluid pours into the space between the chitinous and the hypodermal sacs. The chitinous sacs are ballooned out until their walls become quite tense, and the secretion, which serves to moisten the ova, presumably with the object of preventing or delaying desiccation, percolates through the thin membranous chitin. We have never seen the sacs in the everted condition in *Argas persicus*, and are unable to say whether the secretion transudes through the actual substance of the chitin, which, it may be remarked, is excessively thin, or whether the chitin is perforated by minute pores such as appear to be scattered over the surface of the everted sacs in *Haemaphysalis punctata*. It is impossible to distinguish such pores in the collapsed state of the sac.

How the everted chitinous sacs are withdrawn into the hypodermal sacs during and after the act of oviposition, it is not easy to explain. So far as we have been able to observe, they are not connected with any part of the hypodermal sacs, except at the external opening of the organ. The rhythmical movements of the everted sacs, which are exhibited during the act of oviposition, may be brought about by the contractions of the muscles which are attached to the proximal extremity of the hypodermal sacs, and we can only suggest that the natural elasticity of the **S**-shaped longitudinal folds, together with the action of these muscles and the absorption of the residual fluid remaining in the space between the chitinous and hypodermal sacs, helps to bring about the re-invagination of the chitinous sac and its restoration to the normal resting position.

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[1] Nuttall, G. H. F. (VII. 1908), pp. 16, 17 repr.

The Genital Organs of the Male.

Plate XXVII, *see also* Part II, Plates XV and XVI.

The genital organs of the male comprise the following parts:

1. The Testis.
2. The Vasa Deferentia.
3. The Seminal Vesicle.
4. The Ductus Ejaculatorius.
5. The Accessory Glands.

The Testis.

Plate XXVII, fig. 1, *tes.*

The *testis* is situated in the posterior part of the body, in a position, corresponding precisely, in its relations to the surrounding organs, with that of the ovary in the female. It consists of a slightly irregular, more or less convoluted, flattened tube of a yellowish-white colour, smaller in diameter than the ovary, but of about equal length—*i.e.* approximately one-half of the body width.

The outer wall of the testis is formed by a thin sheath of connective tissue, within which, in young immature males, a single layer of epithelial cells of large size appears. These cells are the *spermatogonia,* which, as the testis developes, proliferate, passing by two successive maturation divisions through the *spermatocyte* stage to the final or *spermatid* form. Each *spermatogonial* cell thus gives rise to four *spermatids,* which are transformed without further division into spermatozoa. As usually seen in sections, the lumen of the greater part of the testis is packed with *spermatids,* which are at first enclosed in "pockets" formed by thin partitions of connective tissue which extend from the investing connective tissue sheath of the testis. As the spermatids increase in size, the "pockets" break down, and the now free spermatids pass from the lumen of the testis to the vas deferens where they rapidly assume the elongated form of the mature spermatozoa.

The Vasa Deferentia.

Plate XXVII, figs. 1–2, *vd.*, *vd'.*

The *vasa deferentia* are a pair of long ducts which issue from the lateral extremities of the testis, and, after a tortuous course, open into an unpaired median seminal vesicle.

The diameter of these ducts shows a remarkable range of variation in the different sections of their course. The first section of the vas deferens consists of a tube, the diameter of which barely exceeds that of the Malpighian tubules; this narrow portion is disposed in a number of small convolutions near the extremities of the testis. The duct then undergoes a sudden and marked enlargement in calibre, and after running for a short distance in the direction of the lateral margin of the body, it loops round and continues its course in an anterior direction, passing along the lateral margins of the accessory glands to a point situated some little distance posterior to the external genital opening, where it is again reflected backwards, and after running in the posterior direction for a short distance, turns in towards the middle line of the body and, with its partner of the other side, terminates the median *seminal vesicle*.

The portion of the vas deferens lying between the narrow proximal section described above and the place of reflection near the external genital opening, is invariably of much greater diameter than the remainder of the duct, and as this dilated position is filled with spermatozoa, Heller termed this portion the *Semenblase* while he referred to the proximal narrow portion as the *vas efferens*[1]. The portion of the vas deferens lying between the dilated section and the median *seminal vesicle*, though considerably smaller in diameter than the middle section, is not nearly so narrow as the proximal section. This terminal section was described by Heller as the *ductus deferens*, who included the whole median unpaired terminal section—the seminal vesicle and the terminal portion of the genital canal—in the term *ductus ejaculatorius*.

The wall of the vas deferens is thin, particularly in the dilated section. It is formed of an outer muscular sheath consisting of both circularly and longitudinally disposed fibres, and a lining epithelium of large flattened cells. The epithelial cells of the proximal narrow portion of the duct approach the columnar form, and are further distinguished by the fact that their boundaries are more clearly defined by cell membranes than is the case with the flattened cells which line the rest of the duct.

The Seminal Vesicle.

Plate XXVII, figs. 2–4, *v. d. c.*

The *seminal vesicle* is formed by the union of the vasa deferentia; it is a thin-walled sac of triangular form situated in the middle of the body in a position corresponding to the uterus of the female, but is almost completely concealed from view by the lobes of the accessory glands which are closely applied to its ventral, posterior and lateral surfaces. Its anterior angle is just visible in the figure which shows the lateral aspect of the accessory glands (Plate XXVII, fig. 2), and in the figure of the ventral aspect of the male genitalia (Plate XXVII, fig. 1) the posterior margin is represented by the dotted line which crosses the middle portion of the accessory glands.

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[1] Heller, C. (1858), pp. 317–320.

Into the posterior angles of the seminal vesicle, the vasa deferentia open, and at the anterior angle, the sac opens downwards into a constricted space (Plate XXVII, fig. 3, *c.g.com.*) which forms a communicating passage between the seminal vesicle and the terminal portion of the common efferent duct which runs directly to the external genital opening. This constricted portion of the genital canal receives the openings of the ducts of the accessory gland, and appears to be the place in which the spermatophores are formed. The walls of the seminal vesicle are identical in their structure with those of the vasa deferentia.

The Ductus Ejaculatorius.

Plate XXVII, figs. 1–3, *c.g.com.*

This is the terminal section of the genital tract through which the products of the testis and the accessory glands reach the exterior of the body. Like the vagina of the female, its internal surface is lined throughout with a thin chitinous sheath which, at the external genital opening, continues directly into the general cuticle of the body. This chitinous intima is continued within the genital canal as far as the anterior opening of the seminal vesicle, and, therefore, the constricted space mentioned above, being lined with chitin, must therefore be considered as a part of the ductus ejaculatorius. The remaining portion is a flattened canal which runs directly to the external genital opening. In its general structure, the ductus ejaculatorius closely resembles the vestibular portion of the vagina of the female. The chitinous layer of the ventral wall is very thin and flexible, while that of the dorsal wall is stout and attains a considerable thickness towards its lateral margins.

The muscles of this part of the genital tract consist of two sets, one of which, the *dorsal genital muscles,* consists of a dense cluster of small bundles which originate from the ventral surface of the endosternite and are inserted into the proximal portion of the flat dorsal surface of the canal; while the other set comprises the *ventral genital muscles*, which originate from the ventral body wall and are inserted on the ventral surface of the ductus ejaculatorius, further forward than the site of insertion of the corresponding dorsal series.

The Accessory Glands.

Plate XXVII, figs. 1–4.

The accessory glands comprise a large and complex mass of peculiar glandular tissue which almost completely surrounds and conceals the seminal vesicle and the terminal portion of the vasa deferentia; and, on account of the dense chalky-white appearance which they usually present, they have been frequently termed the "white glands."

Glandular appendages of divers forms are generally found to be associated with the terminal portion of the genital tract in the *Arachnida*, but, so far as we are aware, in no representative of the class do they ever attain the high degree of development which they exhibit in the *Ixodoidea*.

Heller gave a very good account of their gross structure in *Argas persicus*, though some of his observations were not free from error[1]. Pagenstecher described the structure in *Ixodes ricinus* as a "seminal vesicle[2]," and expressed doubts as to the existence of any actual accessory glands in connection with the male genitalia of this species. His figure (Taf. II, fig. 12) of the male genital organs, however, leaves no doubt whatever as to the presence of the accessory glands in this species. It may be remarked that Pagenstecher made some very strange errors in his observations on the anatomy of the genital organs of *Ixodes ricinus*, for, in both sexes, he failed to recognise the median, transversely-placed *gonad*, and described the dilated portion of the *oviduct* and of the *vas deferens* as the *ovary* and *testis* respectively. The more recent literature, for the most part, contains only casual references to the subject of the accessory genital glands of the male tick; the only author, so far as we know, who has attempted a detailed description, being Bonnet, whose observations, so far as they go, coincide with ours[3].

In its external appearance, the *accessory gland* is a large bilaterally-symmetrical organ which rests on the floor of the body cavity, its anterior extremity, consisting of a single pair of club-shaped lobes, extending almost to the postero-ventral margin of the basis capituli, while the posterior lobes of the organ lie in contact with the anterior surface of the rectal sac, and may even extend backwards for some distance in the lateral regions of the body on either side of the latter.

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[1] Heller, C. (1858), pp. 319, 320.

[2] Pagenstecher, H. A. (1861), p. 39.

[3] Bonnet, A. (1907), pp. 120–122.

An examination of sections of the gland shows it to be composed of two distinct types of tissue, the one of a *spongy* nature and the other *granular*. Each type is confined to certain lobes of the gland, and in no case do the two types appear together in any one lobe.

The lobes which are composed of spongy tissue are attached by their bases to the lateral and ventral walls of the constricted proximal portion of the *ductus ejaculatorius*; they are four in number and from their respective positions may be termed the *anterior* and the *posterior spongy lobes*. The *anterior lobes*, as mentioned above, extend forwards on either side of the external genital opening almost to the basis capituli; the *posterior lobes* run backwards along the middle of the lateral surface of the body of the gland, and almost reach the posterior limits of the organ. Fig. 3 (Plate XXVII) represents a transverse section passing through the anterior opening of the *seminal vesicle*, the constricted proximal portion of the *ductus ejaculatorius* and the four *spongy lobes*. The upper pair of the latter are the *anterior lobes* and the lower and larger pair the *posterior lobes*. In structure, the *spongy lobes* are seen to consist of a connective tissue stroma, the lacunae of which are distended with a clear pale secretion. The external surface is closely invested by a delicate connective tissue sheath, near which most of the nuclei lie. The latter are of moderate size and ovoid in shape; they are very rich in chromatin, which is distributed in irregular clumps immediately beneath the nuclear membrane. Isolated nuclei, which show appearances of dissolution, are scattered in limited numbers in the more central portions of the lobe. The lacunar spaces of the stroma unite to form a short duct (*d. a. s. l.*, *d. p. s. l.*) within the substance of the gland, which opens directly into the constricted portion of the *ductus ejaculatorius*; through its lateral walls in the case of the *anterior lobes*, and by a pair of adjacent openings in its floor in the case of the *posterior lobes*.

The remaining lobes, which form the greater part of the accessory gland, are collectively of the *granular type*, and, unlike the spongy lobes, they all derive their origin as offshoots of a small median unpaired lobe which lies in the anterior portion of the ventral part of the body of the gland. Fig. 4 (Plate XXVII) represents a transverse section which passes through this *median granular lobe* of the white gland, on either side of which lies one of the posterior spongy lobes, and the ventral wall of the seminal vesicle above.

Like the spongy lobes, the granular lobes are invested in an outer capsule of connective tissue, but their internal structure presents a very different appearance. The lumen of the median granular lobe is represented by a narrow vertical cleft, and the entire space between the lumen and the capsule is filled with a singular columnar structure. The basal portion is formed of more or less recognisable cylindrical cells, the free extremities of which break into a columnar succession of large granules of an irregular spheroidal or polyhedral form, which are supported by a delicate interpenetrating stroma of connective tissue. These granules constitute the secretion of the gland and appear to aggregate into larger spherical masses or globules as they become free within the lumen. The basal cells are furnished with large rounded or elliptical, deeply-staining nuclei, and other nuclei in various stages of dissolution are distributed irregularly throughout the granular zone. The granules are strongly basophile in their reaction to dyes. The granular lobes all conform in their structure to the foregoing description, but may show minor differences in the details (see Pl. XXVII, fig. 5 *a–b*).

Near the posterior end of the *median granular lobe*, the lumen divides into four divergent parts, two of which are disposed vertically above one another; and the other two of which diverge laterally to form the lumen of the *first pair* of *lateral granular lobes* (see Text-fig. 8, D). Of the former, the ventral lumen runs directly backwards and downwards and soon comes to a blind termination, while the upper lumen continues backwards along the main axis of the body of the gland, and gives off, successively, two more lateral lobes—the *second* and *third lateral granular lobes*—the second lateral lobe being the smallest of the series. The axial lumen then divides once more in the vertical direction, giving off a pair of *postero-dorsal granular lobes*, and a single broad median lobe which passes upwards through the fork formed by the union of the vasa deferentia with the seminal vesicle, and turns forwards along the dorsal surface of the seminal vesicle where it forms a median unpaired *antero-dorsal granular lobe*. The postero-lateral angles of this lobe are generally swollen out as a pair of conspicuous spherical bosses. The lumina of all these granular lobes communicate with that of the *median granular lobe*, which at its anterior extremity opens directly through the posterior wall of the constricted proximal portion of the *ductus ejaculatorius*, into the cavity of which it discharges its secretion.

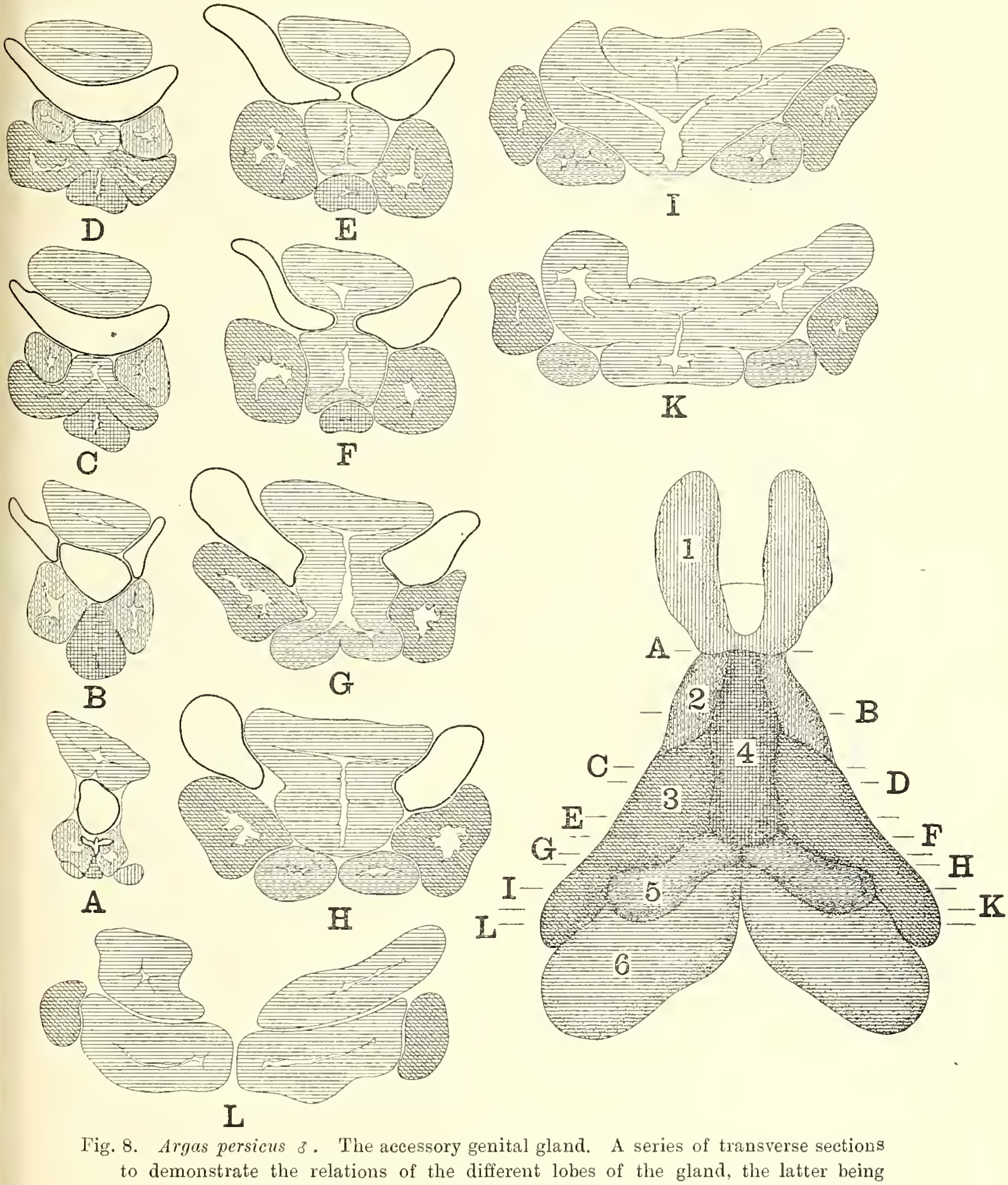

Fig. 8. *Argas persicus* ♂. The accessory genital gland. A series of transverse sections to demonstrate the relations of the different lobes of the gland, the latter being distinguished by the various styles of shading. In the figure of the ventral aspect of the entire gland, the different lobes are numbered, while the planes of the sections are indicated by the corresponding letters. 1. *anterior spongy lobe;* 2. *posterior spongy lobe;* 3. 1*st pair of lateral granular lobes;* 4. *median granular lobe;* 5. 2*nd lateral granular lobes;* 6. 3*rd lateral granular lobes.* In the sections, the *antero-dorsal* and *postero-dorsal granular lobes*, as well as the 3*rd lateral granular lobes*, are distinguished by horizontal line shading.

The thick lines in sections *A–H* represent the sections of the seminal vesicle and the vasa deferentia.

The function of the secretion of the accessory gland is apparently twofold. It is responsible for the formation of the thin chitinous capsules of the spermatophores; and its fluid secretion serves as a diluent of the seminal fluid; while the granules suspended in this fluid, evidently identical with the secretion of the granular lobes, may possibly serve for the nutrition of the spermatozoa during their more or less lengthy sojourn in the uterus and oviducts of the female.

The Spermatozoa.

Plate XXVII, fig. 6 *a–d*.

As they appear in the vasa deferentia and the seminal vesicle of the male, the spermatozoa are stout, cylindrical rod-like bodies measuring about 0·2 mm. in length and 10 μ in diameter. The nucleus is represented by a linear streak of chromatin situated on the periphery of the body near one extremity.

The body of the spermatozoan, as seen in its entirety, exhibits a peculiar arrangement of the cytoplasm, which has the appearance of a number of stout longitudinal strands of deeply-staining cytoplasm. In transverse sections of the spermatozoan, these more deeply-stained internal parts resolve themselves into two concentric sheaths, the inner of which is generally thrown into one or more continuous longitudinal folds owing to the narrow limits of the space in which it is confined. A careful examination of the entire spermatozoan shows that the inner sheath is formed as an invagination of the outer sheath, the place of continuity of the two sheaths being distinctly visible at one extremity of the body.

When the spermatozoa ultimately escape from the spermatophore in the uterus of the female, the inner sheath is then completely evaginated, and the spermatozoan becomes almost doubled in length.

Unfortunately, we have not had an opportunity of following the remarkable sequence of transformations through which the spermatozoan passes after it leaves the testis of the male, but from what observations we have made, the process appears to be identical with that exhibited by the spermatozoa of *Ixodes ricinus*, which has been the subject of an interesting paper by Samson[1] to which the reader is referred.

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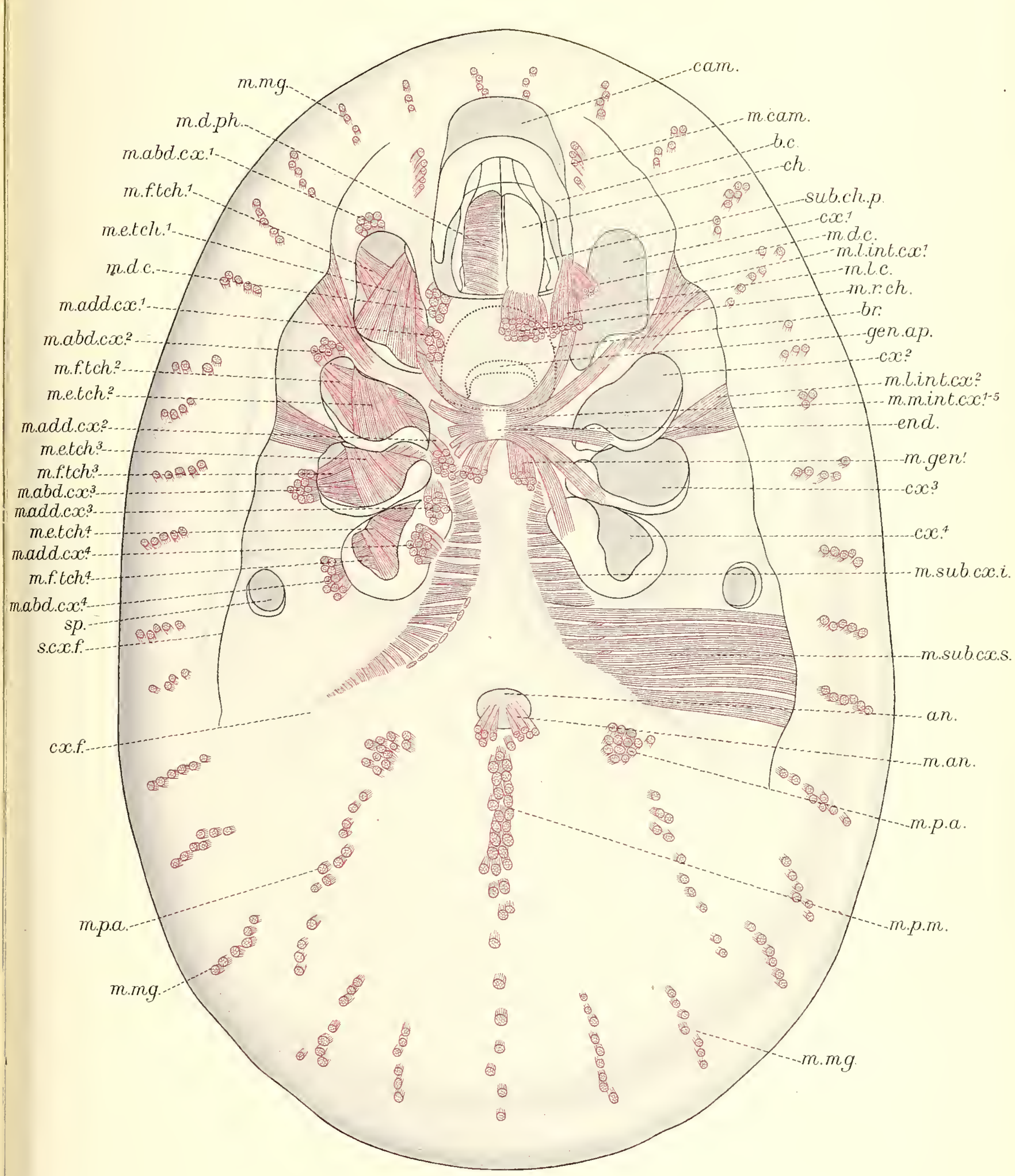
[1] Samson, K. (1909 *b*).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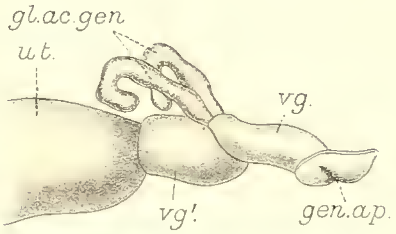

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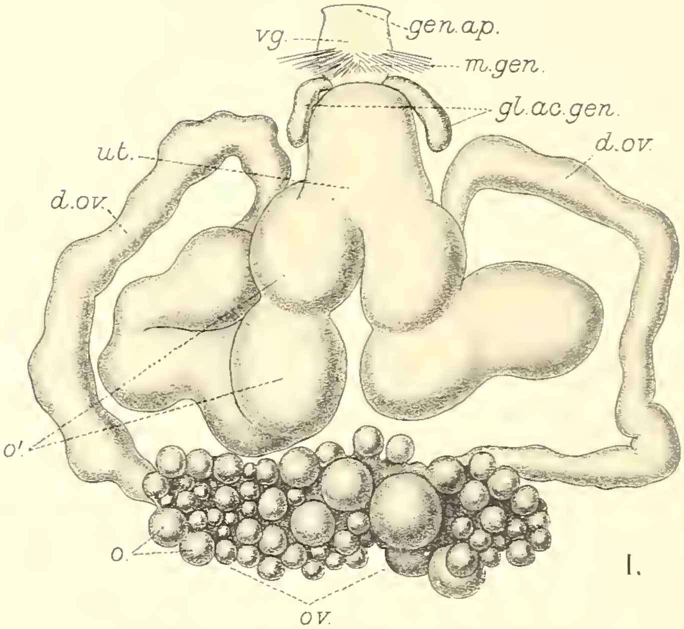

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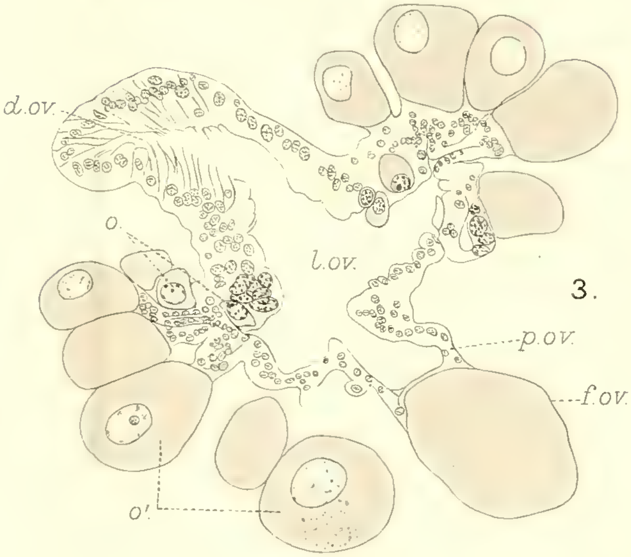

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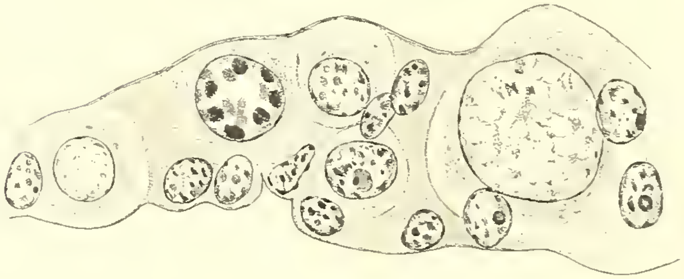

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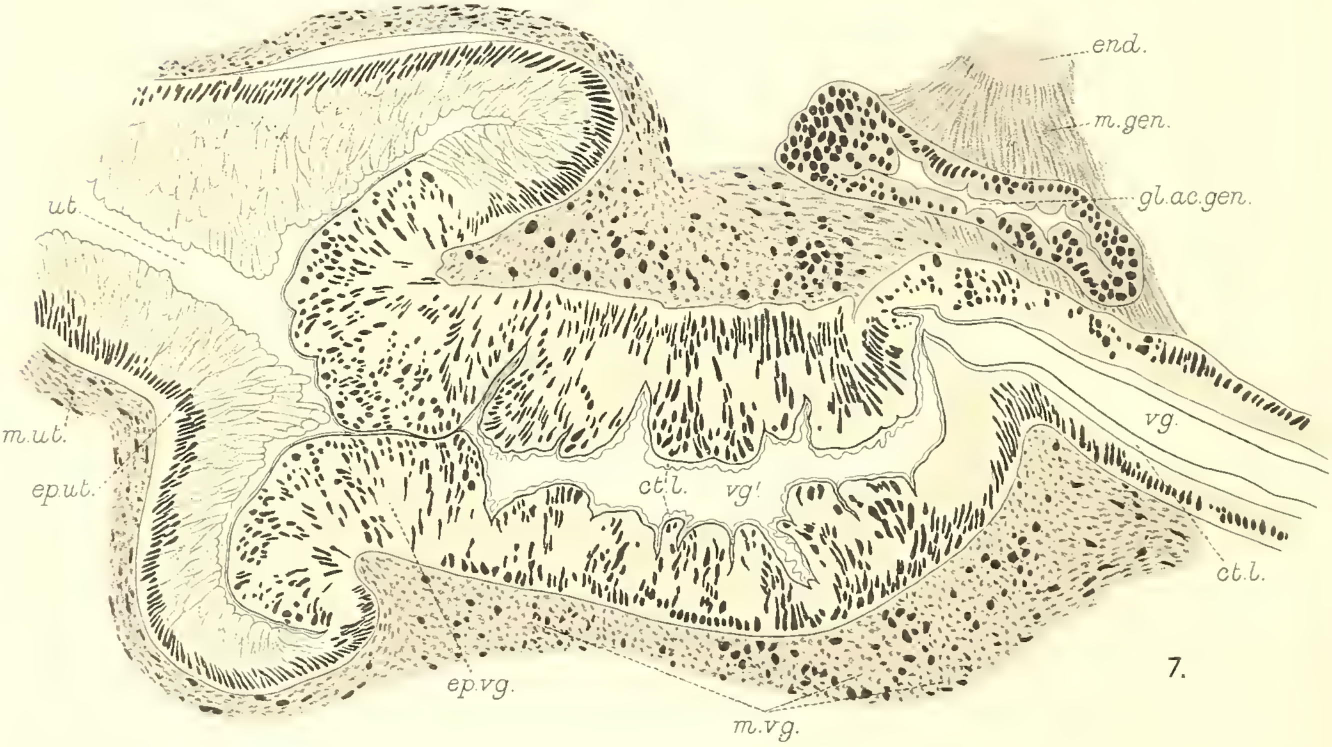

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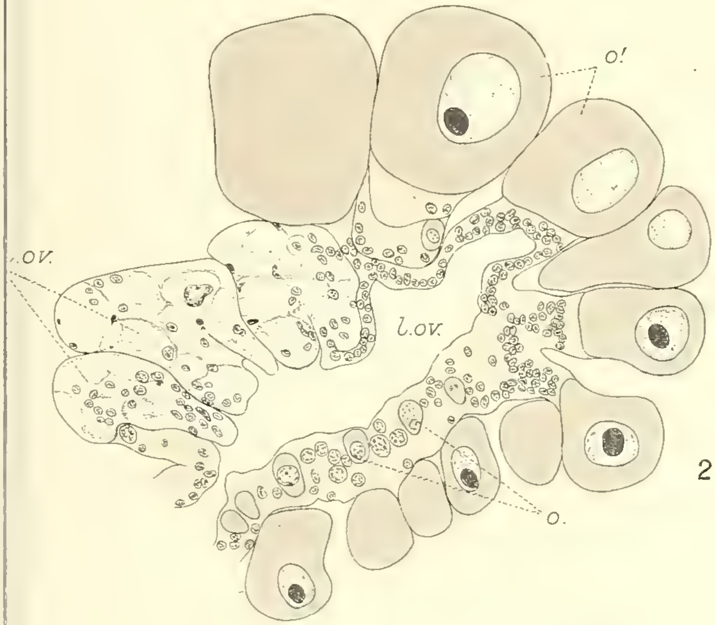

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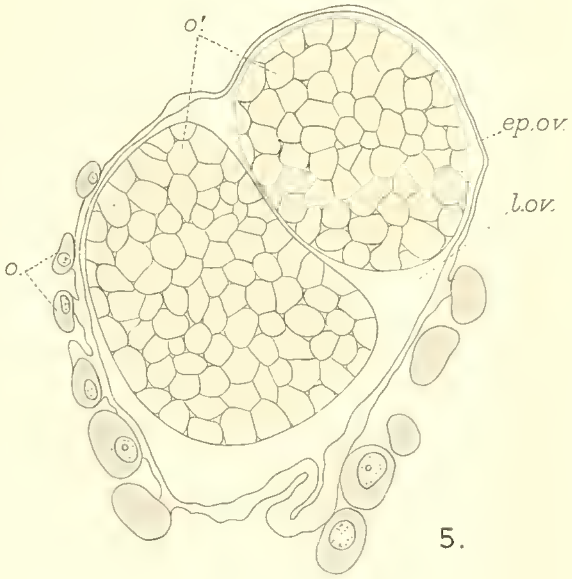

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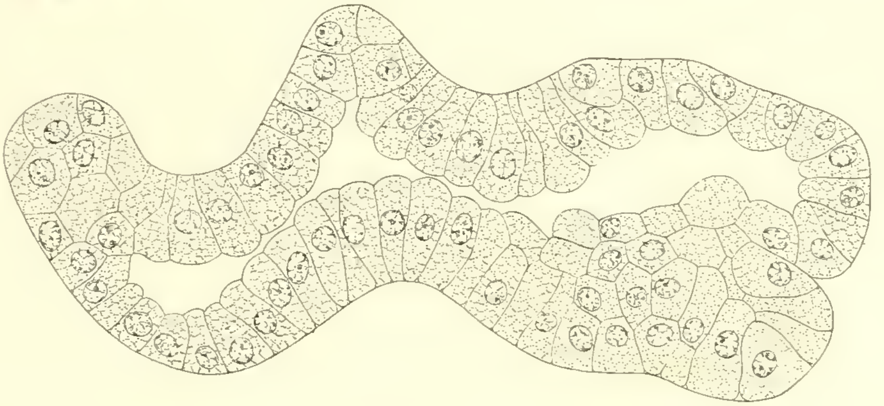

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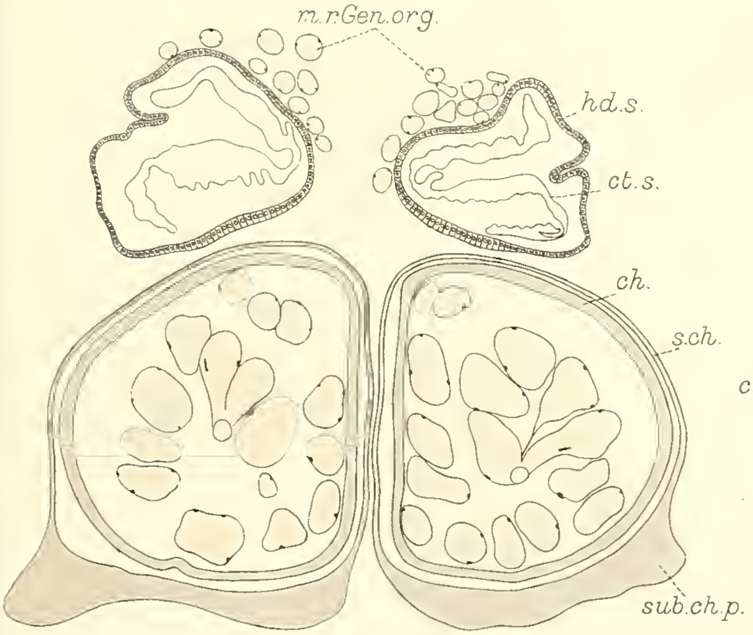

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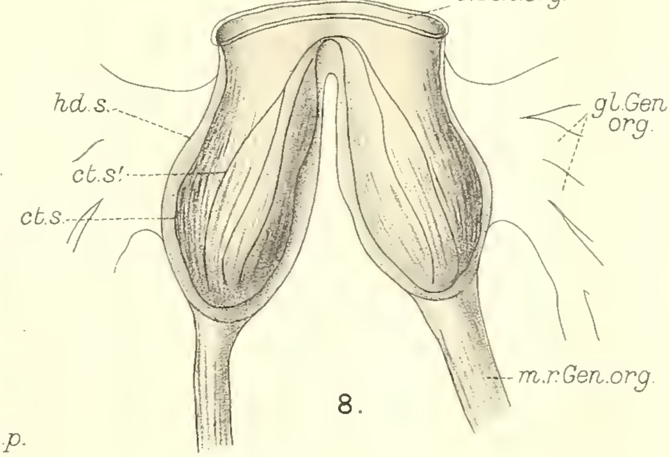

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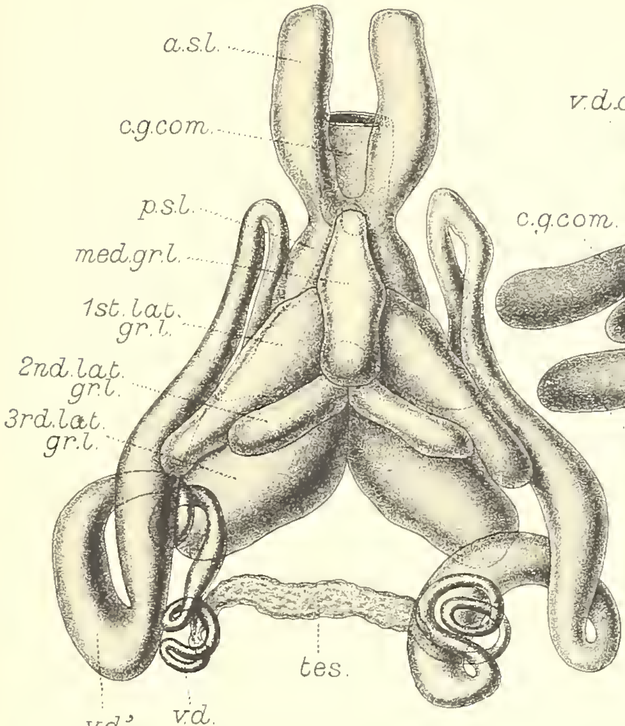

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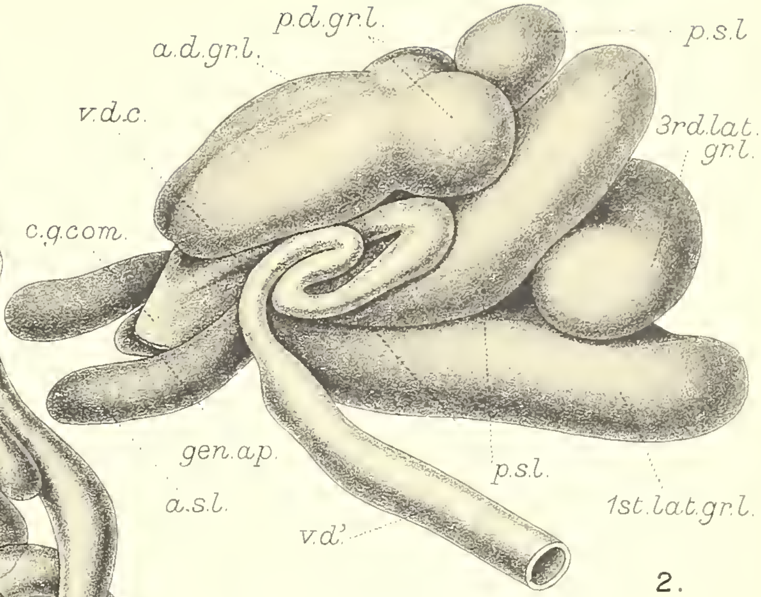

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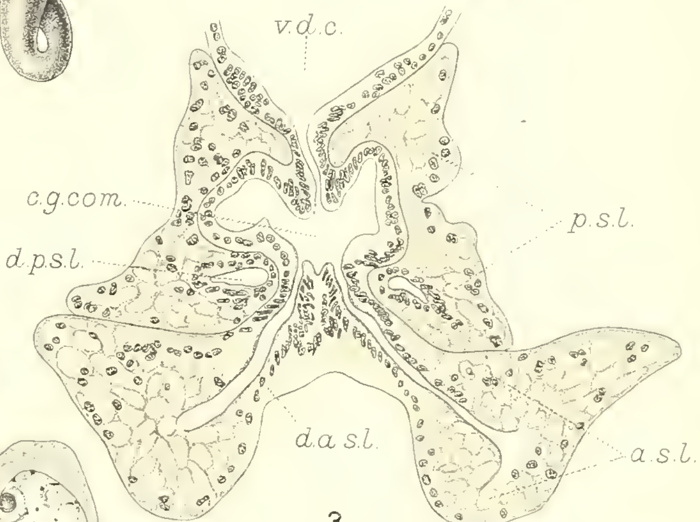

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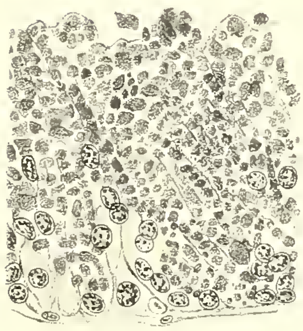

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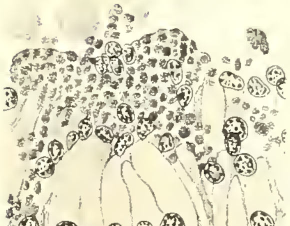

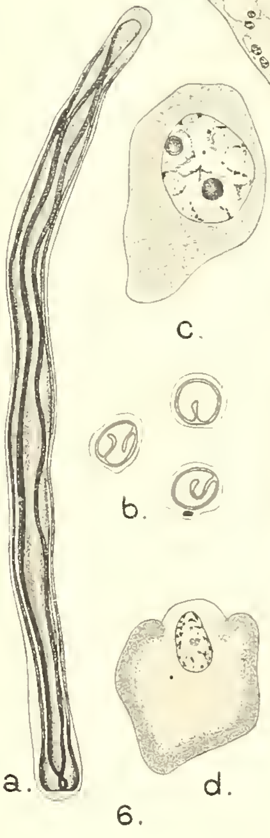

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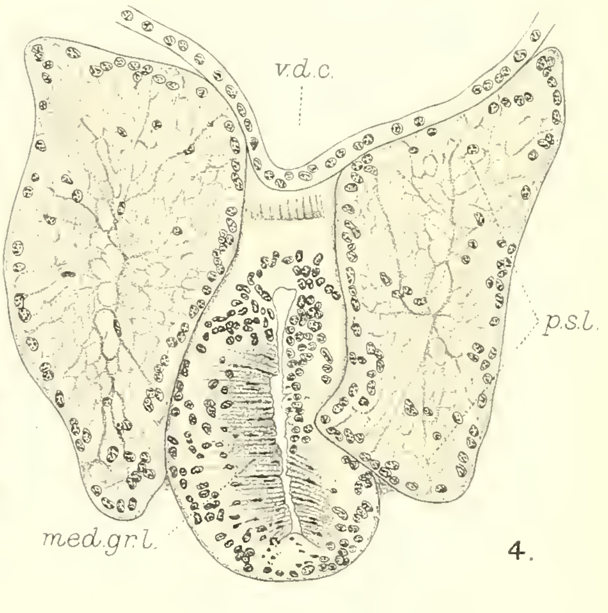

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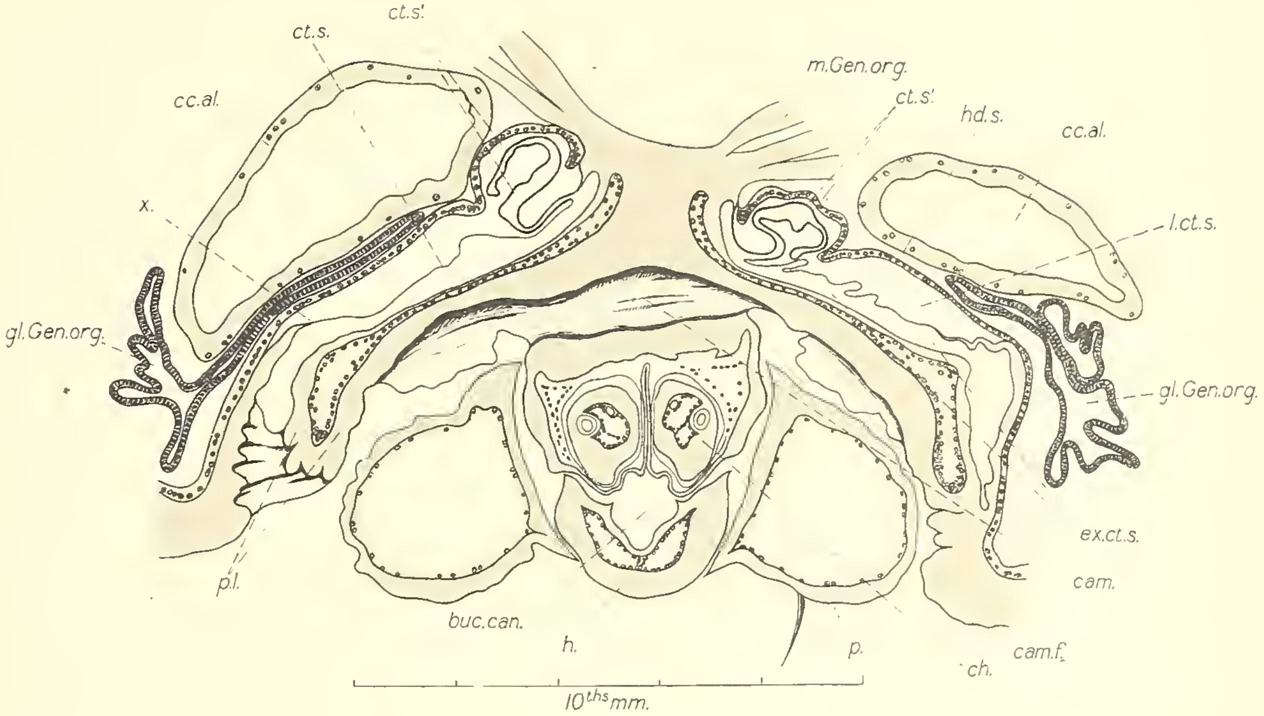

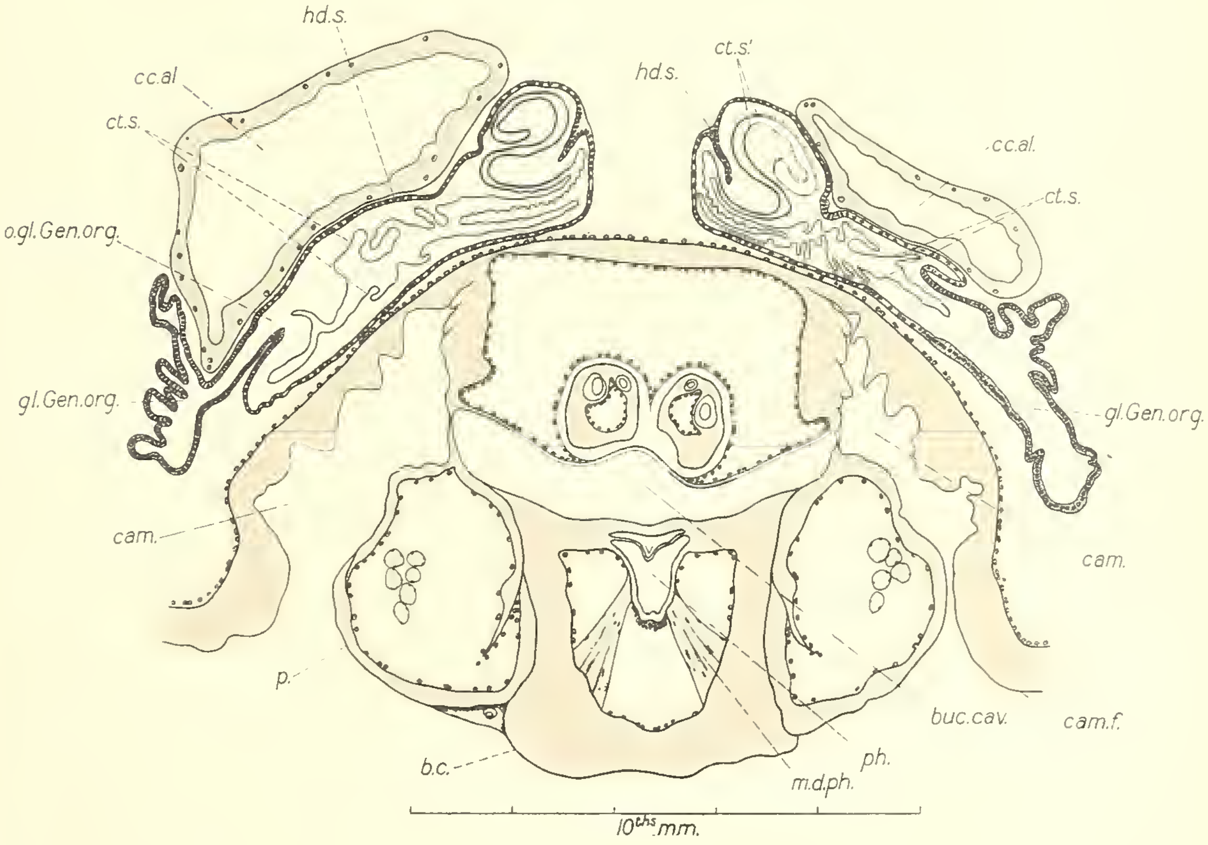

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EXPLANATION OF PLATES XXV TO XXVIII.

PLATE XXV. *Argas persicus.*

The muscular system of the male as displayed after the removal of the dorsal integument and the viscera. Magn. 25 diam.

PLATE XXVI. *Argas persicus.* Female.

Fig. 1. The genital organs from the dorsal aspect. This figure shows the condition of the genitalia just before the commencement of oviposition and should be compared with the earlier condition illustrated on Plate XIV, Part II. Magn. 25 diam.

Fig. 2. Transverse section of the ovary of an unfed female, showing the ovarian epithelium with ova (*o. o'.*) in various stages of development, and the ovarian gland (*gl. ov.*). Magn. 125 diam.

Fig. 3. Transverse section of the ovary at the place of origin of the oviduct. The youngest ova (*o.*) are still completely embedded in the thickness of the ovarian epithelium, while the more mature ova (*o'.*) lie without the wall of the ovary, to which they remain attached by the pedicels (*p. ov.*). Magn. 125 diam.

Fig. 4. Section of a portion of the wall of the ovary in a very young female (*deutero-nymph* ?), showing the earlier stages in the development of the ova. Magn. 1000 diam.

Fig. 5. Transverse section of the ovary at a late stage, with two large ova lying free within the lumen of the ovarian tubule. It may be observed that these ova are still unprovided with a shell. Magn. 60 diam.

Fig. 6. Terminal portion of the genital tract as seen in dissection from the right side. Magn. 25 diam.

Fig. 7. Median longitudinal section of the cervical portion of the vagina, showing its relations with the uterus and the vestibular portion of the vagina respectively. Magn. 200 diam.

Fig. 8. Gené's organ. The saccular portion in the non-active condition. The eversible chitinous sacs (*ct. s.*) are seen to be suspended within the hypodermal sacs (*hd. s.*). The wide efferent ducts of the glands are represented in plain outline. Magn. 36 diam.

Fig. 9. Gené's organ. Transverse section of the posterior part of the saccular portion, showing the internally situated chitinous sacs (*ct. s.*) and the enveloping hypodermal sacs (*hd. s.*); also the situation of the organ in relation to the shafts of the chelicerae. Magn. 140 diam.

Fig. 10. Gené's organ. Section through one of the lobes of the glandular portion, showing the secretory cells. Magn. 485 diam.

PLATE XXVII. *Argas persicus.* Male.

Fig. 1. The genital organs from the ventral aspect. Magn. 35 diam.

Fig. 2. The genital organs from the lateral aspect: the testis and the upper part of the vasa deferentia have been removed. Magn. 47 diam.

Fig. 3. Transverse section of the genital tract at the place of communication between the seminal vesicle (*v. d. c.*) and the ductus ejaculatorius (*c. g. com.*), showing the constricted proximal portion of the latter, into which the ducts of the accessory glands open. Magn. 260 diam.

Fig. 4. Transverse section through the antero-ventral part of the accessory gland, showing the structure of the median granular lobe and the posterior spongy lobes. Magn. 260 diam.

Fig. 5. Sections of portions of the median granular lobe (*a*) and the 2nd lateral granular lobe (*b*) of the accessory gland. Magn. 350 diam.

Fig. 6. (*a*) Spermatozoan from the seminal vesicle, showing the invaginated condition which persists until the spermatozoa are liberated from the spermatophore in the uterus of the female. (*b*) Transverse sections of spermatozoa showing the concentric sheaths of deeply-staining cytoplasm. (*c*) A young spermatid from the testis. (*d*) Spermatid at a later stage, from the vas deferens, showing the commencement of its evolution into the spermatozoan. Magn. 470 diam.

PLATE XXVIII. *Argas persicus.* Female.

Gené's organ. Two transverse sections through the anterior part of the body, showing the relations of Gené's organ with the external integument. The upper section passes through the fold formed by the junction of the dorsal surface of the basis capituli with the posterior limit of the camerostome. The lower section is taken at a level some distance posterior to the former, but still anterior to the capitular foramen. Magn. 115 diam.

INDEX TO LETTERING ON PLATES XXV TO XXVIII.

a. d. gr. l.	antero-dorsal granular lobe of accessory gland.
an.	anus.
a. s. l.	anterior spongy lobe of accessory gland.
b. c.	basis capituli.
br.	central nerve mass or "brain."
buc. can.	buccal canal.
buc. cav.	buccal cavity.
cam.	camerostome.
cam. f.	camerostomal fold.
cc. al.	alimentary coeca.
c. g. com.	ductus ejaculatorius.
ch.	chelicera.
ct. l.	chitinous lining of vagina.
ct. s.	chitinous sac of Gené's organ.
ct. s'.	thickened S-shaped folds of chitinous sac of Gené's organ.
cx. 1–4	coxae 1–4.
cx. f.	coxal fold.
d. a. s. l.	efferent duct of anterior spongy lobe of accessory gland.
d. ov.	oviduct.
d. p. s. l.	efferent duct of posterior spongy lobe of accessory gland.
end.	endosternite.
ep. ov.	ovarian epithelium.
ep. ut.	epithelial lining of uterus.
ep. vg.	epithelial lining of vagina.
ex. ct. s.	indicates the space, external to the chitinous sac of Gené's organ, which communicates directly with the exterior.

f. ov.	ovarian follicle.
gen. ap.	genital aperture.
gl. ac. gen.	accessory genital glands.
gl. Gen. org.	glandular portion of Gené's organ.
gl. ov.	ovarian gland.
h.	hypostome.
hd. s.	hypodermal sac of Gené's organ.
1*st*–3*rd lat. gr. l.*	1st–3rd lateral granular lobes of accessory gland.
l. ct. s.	indicates the space, between the chitinous and the hypodermal sacs of Gené's organ, which is closed to the exterior.
l. ov.	lumen of ovary.
m. abd. cx. 1–4	abductor muscles of coxae 1–4.
m. add. cx. 1–4	adductor muscles of coxae 1–4.
m. an.	anal muscles.
m. cam.	camerostomal muscles.
m. d. c.	depressor muscles of capitulum.
m. d. ph.	dilator muscles of pharynx.
med. gr. l.	median granular lobe of accessory gland.
m. e. tch. 1–4	extensor muscles of trochanters 1–4.
m. f. tch. 1–4	flexor muscles of trochanters 1–4.
m. gen.	superior genital muscles.
m. gen'.	dorso-genital muscles.
m. Gen. org.	muscles which pass down from the dorsal cuticle to the camerostome, immediately above the external opening of Gené's organ.
m. l. c.	levator muscles of capitulum.
m. l. int. cx. 1–2	lateral intercoxal muscles 1–2.
m. mg.	marginal dorso-ventral muscles.
m. m. int. cx. 1–5	mesial intercoxal muscles 1–5.
m. m. int. cx. (Pl. XXVI, fig. 7)	mesial intercoxal muscles and superior genital muscles.
m. p. a.	postero-accessory dorso-ventral muscles.
m. p. m.	postero-median dorso-ventral muscles.
m. r. ch.	retractor muscle of chelicera.
m. r. Gen. org.	retractor muscle of the hypodermal sac of Gené's organ.
m. sub. cx. i.	inferior subcoxal muscles.
m. sub. cx. s.	superior subcoxal muscles.
m. ut.	muscular layer of wall of uterus.
m. vg.	muscular layer of wall of vagina.
o.	immature ova still embedded in the ovarian epithelium: in fig. 5, ova situated on ovarian pedicels.
o'.	more mature ova situated on the ovarian pedicels: in fig. 5, ova free within the lumen of the ovary.
o. Gen. org.	external opening of Gené's organ.
o. gl. Gen. org.	efferent duct of glandular portion of Gené's organ.
ov.	ovary.
p.	palp.
p. d. gr. l.	postero-dorsal granular lobe of accessory gland.
ph.	pharynx.
p. l.	posterior lip of the external opening of Gené's organ.
p. ov.	pedicel of ovum.
p. s. l.	posterior spongy lobe of accessory gland.

s. ch.	inner sheath of chelicera.
s. cx. f.	supracoxal fold.
sp.	spiracle.
sub. ch. p.	sub-cheliceral plate.
tes.	testis.
ut.	uterus.
v. d.	vas deferens, proximal narrow portion.
v. d'.	vas deferens, distal dilated portion.
v. d. c.	seminal vesicle.
vg.	vagina, vestibular portion.
vg'.	vagina, cervical portion.
x.	indicates the place where the margin of the chitinous sac of Gené's organ continues into the general body integument.

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Besson, A. (1913). *Practical Bacteriology, Microbiology and Serum Therapy.* (Medical and Veterinary.) (Translated and adapted from the 5th French Edition by Dr H. J. Hutchens, D.S.O.) London: Longmans, Green & Co., 39, Paternoster Row. 892 pp., 416 illustrations (149 coloured). 24×16 cm. Price 36/- net. Cloth.

Professor Hutchens' translation of this excellent work, which was published in French in 1911, has the advantage over the original in that the translator has made numerous additions so as to bring the book fully up to date. The book gives a very full account of present day technique and all the important pathogenic bacteria which concern physicians and veterinarians; the pathogenic fungi, protozoan parasites and filterable viruses and the examination of water, sewage and air each occupy a section. The book is illustrated by many good coloured text-figures and is excellently printed on thin paper which prevents the work from being bulky. The book is a first class production. N.

Herms, W. B. (1913). *A Laboratory Guide to the Study of Parasitology.* New York: The Macmillan Company. 72 pp. 22×14 cm. Price 3/6 net. Cloth.

This book will serve as a useful guide to teachers preparing a course of practical instruction in parasitology, for the practical work is divided up into about 40 exercises, each of which provides work for 2½ to 3 hours.

The first section, on Medical Entomology, is carefully arranged to give the student a thorough acquaintance with the various groups of the parasitic Arthropoda, and the types are well chosen; but we think that considering its importance as a disease carrier, *Glossina* might have been included with advantage. The section on Protozoa (4 pages) is incomplete and might well have been omitted, as the examination of the one or two isolated examples mentioned would serve no useful purpose.

The second part of the book is concerned with Helminthology, and finally the author gives a few suggestions for practical work on the life-cycles of one or two insects. E. H.

Howard, L. O., Dyar, H. G. and Knab, F. (1912). *The Mosquitoes of North and Central America and the West Indies.* Volume I. A general consideration of Mosquitoes, their habits, and their relations to the human species. 520 pp. 14 pls., 6 text-figs. Issued by the Carnegie Institution of Washington.

Publication 159. The Lord Baltimore Press, Baltimore, Md., U.S.A. 26 × 18 cm. Volume II contains 150 plates.

The first copies of this monumental work were issued 21 Jan. 1913. The two volumes represent work commenced in 1903 with the aid of grants from the Carnegie Institution of Washington, and from the U.S. Dept. of Agriculture etc.; a part of the expense was defrayed by two of the authors, Messrs Dyar and Knab. Many volunteers have however helped in the work of collecting material. A number of paid investigators were sent to different localities to collect specimens and make studies upon the biology of various species of mosquitoes. The authors themselves travelled extensively for the purposes of the investigation and Dr Howard went to Vienna to examine the Wiedermann and Winthem types.

The authors condemn the genus *Stegomyia*, the familiar *S. fasciata* disappears in favour of *Aëdes calopus.* The so-called *Anopheles maculipennis* (of America) is now *A. quadrimaculatus* and *A. occidentalis.* *Culex fatigans* or *C. cubensis* becomes *C. quinquefasciatus* etc. The authors give a great deal of valuable new information on bionomics.

Following upon an historical introduction the anatomy of mosquitoes in all stages is described, then follow details regarding their biology, enemies, methods of collecting mosquitoes, their relation to disease, remedies against mosquitoes with examples of mosquito control in different parts of the world. Whilst quoting extensively from different authors, due credit is given to others for the work they have done. The bibliography occupies 37 pages and a very full index concludes the volume.

Volume II includes the plates of which there are no less than 150. Of these 39 illustrate the external male genitalia (270 figs.); 1 the wings, 43 the larva seen *in toto*, 58 details in the structure of larvae, the remaining plates illustrating a few of the eggs and pupae of different species. The illustrations of the larvae are exceptionally beautiful, they were executed by one of the authors, Dr F. Knab, a fact which we did not find mentioned in the text. Altogether we have before us a most excellent publication upon which the authors are to be congratulated most heartily. N.

Ross, H. C., Cropper, J. W., Ross, E. H. and others (iv. 1913). *Researches into Induced Cell-reproduction and Cancer* and other papers. Vol. III. (The John Howard McFadden Researches.) London: John Murray, Albemarle Street, W. 149 pp., 17 coloured plates, 8 figs. 23 × 14 cm. Price 5/- net. Cloth.

This volume consists of a collection of papers including such diverse subjects as "The Problem of the Gasworks Pitch Industries and Cancer," "Protozoal Parasites found in Syphilis," and the cultivation of trypanosomes. Many of the articles have been previously published elsewhere.

The descriptions of parasites seem to be based mainly on the appearances presented by films prepared by the so-called "jelly method," whilst, in the case of those papers dealing with malignant growths, the theory of auxetics is called in to explain their origin. The descriptions of the life-cycles of the *Lymphocytozoa* are of a highly speculative character and very unconvincing, and before accepting the theories advanced by the authors independent confirmation is much to be desired.

The plates illustrating the book are of very unequal merit, some of the photographs being utterly worthless (*e.g.* Pls. III, IV, X); but most of the coloured figures are well reproduced. E. H.

SMALLWOOD, W. M. (1913). *A Text-book of Biology.* London: Baillière, Tindall & Cox, 8, Henrietta Street, Covent Garden. 285 pp., 13 pls. and 243 illustrations. 24 × 16 cm. Cloth.

The author of this book is Professor of Comparative Anatomy in Syracuse University and has charge of the Department of Forest Zoology in the New York State College of Forestry at Syracuse. Professor Smallwood therefore writes with the authority of an investigator and teacher familiar with the wants of the student. His plan of study for the commencing student is based upon the historical development of biological science which is briefly outlined in the preface. Chapters I—IX deal with the organism as a whole, the structure and functions of the organs, tissues and cells. Chapters X and XI deal with the biology of cells, of bacteria, yeasts and moulds, and Chapters XII—XVIII with Vermes, Arthropods, plants, biological adaptation, biological factors in disease, evolution, variation and heredity, animal behaviour and its relation to mind. A Glossary and Index conclude the volume. The illustrations are mostly borrowed but good judgment has been used in their selection. The book presents an excellent appearance and should well serve the purpose for which it is destined by the author. N.

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